Technical Report 842

Computer-Mediated Group Processes in Distributed Command and Control Systems: Dyad Shared Work

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This report describes research and findings on the effects of computer-mediated communications on distributed command and control. To support collaboration among distributed remote command staffs, computer-mediated communications may be needed to share information, provide supervision, coordinate operations, perform analyses, and provide recommendations. This may require computer aiding, shared graphics, shared data bases, and two-way graphic communication. To test the potential of computer-mediated communication, an experiment was conducted that required two people to collaborate on a tactical movement order task. Both people were also required to perform other work to simulate conditions typical for command staffs. Measures were taken on the performance of primary and other work and of features on the communication transcripts. Work was performed face-to-face (FTF) and with the two people separated using various modes of computer-mediated communications. Of interest were voice or voiceless communications and synchronous or asynchronous communications. The
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following experimental modes were selected: (1) face-to-face (FTF), (2) synchronous with voice communications (SYNCH+V), (3) synchronous without voice communications but with the exchange of typed computer messages (SYNCH-V), and (4) voiceless asynchronous electronic-mail communications (ASYNCH). This experiment studied the effects of communication modes on task performance. A priori comparisons of the FTF mode and the other three modes were performed. The differences between FTF and SYNCH+V conditions were negligible. Results indicate that little is lost in terms of performance quality or speed when moving from face-to-face to computer-mediated communications with an auxiliary voice channel. There were notable time differences from these two modes to SYNCH-V and ASYNCH modes. Combat developers of command and control systems should consider computer-mediation as a viable alternative to face-to-face and voice-only communications.

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FOREWORD

Command and control (C2) operations and supporting combat staff work require effective communication among both face-to-face and separated soldiers. Plans for using computers to aid staff processes must take into account changes from traditional means of communication to computer mediation. This is especially true for distributed modes of performance. The interaction between team members working jointly to solve a problem or to perform a task is affected by the capabilities of the available tools. To date, researchers have adequately anticipated problems or identified opportunities for the use of tools to perform analyses and develop plans. Tactical computer design has been focused too narrowly on the transmission and presentation of information and not information use.

The Fort Leavenworth Field Unit has initiated research on C2 staff operations to address issues of computer mediation. This report provides findings on differences in performance when using various modes of computer communication for a team developing a movement plan. The results have general implications for the design of tactical computers, but more importantly apply to the design of procedures for using computers to support distributed staff performance.

EDGAR M. JOHNSON
Technical Director

COMPUTER-MEDIATED GROUP PROCESSES IN DISTRIBUTED COMMAND AND CONTROL SYSTEMS: DYAD SHARED WORK

EXECUTIVE SUMMARY

Requirement:

The military command and control (C2) system is functionally and geographically distributed. However, future C2 systems will be even further distributed to increase survivability and breadth of command control. Voice communications alone may not adequately support the distributed staff cooperating to perform military tasks. Computer networks offer the promise of providing enhanced group communications. To support collaboration among distributed remote command staffs, computer-mediated communications may be needed to share information, provide supervision, coordinate operations, perform analyses, and provide recommendations. This may require computer aiding, shared graphics, shared data bases, and two-way graphic communication.

Procedure:

To test the potential of computer-mediated communication, an experiment was conducted that required two people to collaborate on a task based on a military tactical movement order. Additionally, both people were required to perform other work to simulate an environment typical for command staffs. Measures were taken on the performance of primary and other work and on features of the communication transcripts.

Work was performed face-to-face and with the two people separated and using various modes of computer-mediated communications. Of interest were voice or voiceless communications and synchronous (real time, what one sees is what the other sees) or asynchronous (delayed, electronic mail) communications. The following experimental modes were selected: (1) face-to-face, (2) synchronous with voice communications (SYNCH+V), (3) synchronous without voice communications but with the exchange of typed computer messages (SYNCH-V), and (4) voiceless asynchronous electronic-mail communications (ASYNCH).

The laboratory task generally required the development of a movement plan by the operations planning cell of a division command post. The plan required coordination among major functional staff groups and collaboration within a single functional group. The subtasks included in the laboratory manifestation required (1) route selection and (2) computation and creation of movement tables.

The dyad's route selection task was to select the shortest route satisfying a number of task requirements (e.g., avoid engaging in battle while enroute, units will not spend more than 10 total hours on the road per day, rest stops of 20 minutes must be planned for every 3 hours of travel). The route selection task required extensive use of graphics and the solution was presented in terms of a graphic. The movement table task involved completing entries in preformatted tables to reflect start and stop times, meal and rest stops, and overnight stops.

An overall data analysis was performed and the effects of communication mode on each dependent variable were assessed. These analyses were followed by a transcript analysis of the spoken and typed communications between participants. A within-dyad repeated measures ANOVA was performed on each dependent variable. The within-group factors (fixed effects) were trials and communication modes. Eight two-person dyads performed each of the four communication modes, two trials per dyad.

The main goal of this experiment was to study the effects of communication modes on task performance. To accomplish this goal, a priori comparisons of the FTF mode and the other three modes were performed. The contrasts were (1) FTF versus SYNCH+V, (2) FTF versus SYNCH-V, and (3) FTF versus ASYNCH.

Transcripts of communications between dyad members were analyzed. The independent variables were TRIALS and MODES. A number of dependent variables were analyzed.

Findings:

The differences between face-to-face and synchronous with voice conditions were negligible. Little is lost in terms of performance quality or speed when moving from face-to-face to computer-mediated communications with an auxiliary voice channel. There were notable differences between these two modes and synchronous without voice and asynchronous modes. The existence or nonexistence of a voice communication channel appears to be most responsible for performance differences rather than physical separation or computer-mediation.

Utilization of Findings:

Combat developers of command and control systems should consider computer mediation as a viable alternative to face-to-face and voice-only communications. The benefits of computer aiding, shared graphics, shared data bases, and two-way graphic communication have the potential of creating an environment that accommodates distribution of function and dispersion of assets.

Two steps logically follow this research. The first examines the differences in how supervisory functions are performed in the various modes. The second addresses whether reliance on voice communications can be reduced by making the computer-mediated mode richer through the development of a symbolic graphic communication language. The results of these efforts will be documented in subsequent reports.

COMPUTER-MEDIATED GROUP PROCESSES IN DISTRIBUTED COMMAND AND CONTROL SYSTEMS: DYAD SHARED WORK

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COMPUTER-MEDIATED GROUP PROCESSES IN DISTRIBUTED COMMAND AND CONTROL SYSTEMS: DYAD SHARED WORK

INTRODUCTION

The military command and control (C2) system is functionally and geographically distributed already. However, future C2 systems will be distributed even more in order to increase survivability and breadth of command and control. Voice communications alone may not adequately support distributed staffs cooperating to perform military tasks, but computer networks offer the promise of providing the needed enhancement of group communications. To support collaboration among distributed remote command staffs, computer-mediated communications may be needed to share information, provide supervision, coordinate, perform analyses, and provide recommendations. This may require computer aiding, shared graphics, shared data bases, and two-way graphic communication.

To test the potential of computer-mediated communication, an exploratory experiment was conducted which required two people to collaborate to perform a task based on a military tactical movement order. Each individual possessed part of the information to do the task which had a graphical subtask and a computational subtask; additionally, both people were required to perform other work to simulate an environment typical for command staffs. Measures were taken on the performance of primary and other work, and features of the communication transcripts.

Work was performed face-to-face (FTF) and with the two people separated using various modes of computer-mediated communications. The communications included (1) Synchronous communications, in which the computer screens of both remote computers contain the same information at the same time, or Asynchronous communications, in which the individuals share information delayed through electronic mail (both graphics and text), and (2) communications with, and without, normal voice conversations. The following experimental modes were selected: (1) face-to-face (FTF), (2) synchronous with voice communications (SYNCH + V), (3) synchronous without voice communications, but with the exchange of computer messages (SYNCH-V), and (4) asynchronous electronic-mail communications (ASYNCH).

A discussion of the nature and environment of a military staff group is presented first, followed by a presentation of selected findings from communications, group, and computer-mediated research. The experimental task and procedures are then described to provide the context for the empirical results which follow. Conclusions based on these findings, and potential future directions, are discussed.

Army Staff Groups, Environment, and Computers

Typically, a military staff is organized as a cohesive group to assist the commander in accomplishing the mission. Army tactical command and control functions fall into four general classes:

- acquire and communicate information,
- assess the situation,
- determine actions, and
- direct and lead subordinate forces (DaCunto, et al., 1987)

Unlike some non-military groups, the military staff is usually well-organized, highly structured and has formal operating procedures (Meister, 1976). The team is goal, or mission-oriented, with no single individual having all the task information or background knowledge sufficient to complete the task. Information sharing and sub-goal coordination, remotely and locally, are key characteristics of command staff operations.

The command and control (C2) system is a distributed system. The system is dispersed throughout the battlefield, and must rely on communication systems for assistance in task accomplishment. Future C2 systems will require even more distribution and dispersion for survivability and to increase the commander's sphere of influence and breadth of command and control. Distribution may provide increased protection to the force as a whole, but it will not necessarily enhance the survivability of function, information and coordination. Distribution is reflected through physical separation and a functional division of responsibilities.

The mission of a division headquarters is to plan, direct and support the fighting of its brigades and other elements. This planning, direction and support are performed at the three division command posts. Within each command post there are representatives from each of the primary elements of the staff: personnel, intelligence, operations, and logistics. The representatives are organized differently at each command post to perform the primary responsibility of each. Execution of the battle is the concern of the tactical command post, planning for future events at the main command post, and support for the tactical units at the rear command post. Each command post uses a cellular structure, grouping different functional representatives and liaison elements for the performance of different tasks.

To enhance the capability of remote staffs to share information, provide supervision, coordinate on staff tasks, perform analyses and provide recommendations, computer aiding, shared graphics, shared data bases and two way graphic communication may be required to assist the distributed C2 system. Voice communications alone will probably not support the collaboration and coordination required for successful task accomplishment. The technological capabilities of computer networks may improve the ability to share data, resolve conflicts, and provide guidance to yield an accurate, timely and coordinated staff product.

The maneuver battlefield of the future is envisioned as a highly dynamic environment which is constrained not so much by distance as it is by time. Computer support is being introduced actively by the Army to augment command and control procedures in an attempt to reduce decision making time and decrease the burden of manual information processing. Currently the computer is being incorporated into Army settings with minimal changes to the organizations and task procedures. At tactical command and control echelons the computer is being used as a data base storage medium and a message transmission system.

The opportunities of technology have "pulled" Army command and control systems to the point where computers are enhancing or replacing manual functions. (Examples include creation and transmission of reports, tabulation of resources on hand, record-keeping, message transmission, and graphical displays.) At the same time the requirements to address problems (such as growing lethality, increased work pace and information load) have "pushed" Army command and control systems to select functions where immediate payoff would be high and development risk low. The area of shared work has been considered only in a limited sense of transmitting messages and using common data bases. The concepts of remote players working on a task simultaneously or working in a collaborative fashion are on the horizon and in need of advance research.

Collaborative work from non-collocated sites is an especially critical job redesign strategy for tactical command posts. Large command posts have very high and predictable electronic and physical signatures, making them extremely vulnerable to detection and targeting. Once detected, the command post may be the target of electronic exploitation, jamming, disruption or destruction by tactical or special forces or weapons. The feasibility of dispersing into smaller command posts, distributed across the battlefield, is more likely with computer-mediated communication than through traditional means. Distributed command posts also allow an increase in redundancy of function. Survivability of function is supported so that one cell of a command post could take over the functions of another cell, if something should prevent it from operations. The replacement cell would certainly have to understand the task requirements, but may be relatively unfamiliar with the current status of the required function. Computer prompts of embedded task procedues and historical activity can compensate for lack of user familiarity. Both function and command post survivability are thus enhanced by also having the capability to perform work cooperatively without having to be collocated.

In summary, computer-mediated communication may contribute to the success of the distributed C2 system by allowing effective accomplishment of collaborative work from non-collocated sites. Fortunately, computer mediation has been used for problem solving and decision making in the non-military environment. Various findings will be examined in the following section.

Background Research

We can look to several authors for frameworks in which to approach the area of computer-mediated group tasks. Price (1975) provides an excellent overview of relevant variables in computer-mediated communication and uses five categories of variables: media, interaction, individual, group and task. Tasks used to study computer-mediated groups have fallen generally into one of four categories. They are problem solving, choice dilemma, discussion and games (Weisband, Linville, Liebhaber, Obermayer & Fallesen, 1988). Also Dyer (1984) identifies several factors which affect group performance to keep in mind in any group dynamics setting:

- feedback on performance,
- group stability or personnel turnover,
- team coordination and cooperation,
- size of the team,
- work structure and distribution,
- communication structure,
- group planning.

Some of the earliest human performance research on this topic comes from the study of distributed group communications (Chapanis, 1976). The goals of the research were to determine how people communicate naturally with each other when they are required to solve problems, how human communication is affected by communication devices and modes, and what significant system and human variables affect communication. Included among the findings from the studies were that:

- modes with a voice channel lead to faster problem solving,
- voice channels increase the number of words used,
- interruptions are more likely in voice modes,
- in tasks involving exchange of factual information, about half of the time is spent communicating,
- in tasks involving exchange of opinions, as much as 75% of the time is spent communicating,
- more sophisticated communicators can solve problems more quickly.

Experiments comparing voice media (i.e., face-to-face, audio-video, audio only) with written media (i.e., teletyping, remote handwriting) found voice media to result in faster solutions, but little difference in accuracy (Chapanis, Ochsman, Parrish, & Weeks, 1972; Johansen, Vallee, & Spangler, 1979; Kreuger & Chapanis, 1980; Weeks & Chapanis, 1976). The speed differences are directly attributable to delays in typing, transmitting and reading (Hiltz & Turoff, 1978).

The findings have been the same in decision making tasks which require groups to come to a consensus through face-to-face or computer modes (Siegel, Dubrovsky, Kiesler & McGuire, 1986; Hiltz, Johnson & Agle, 1978). In experiments with constrained time, the computer-mediated groups form less consensus than face-to-face groups (Kerr & Hiltz, 1982).

The lack of nonverbal feedback and affective cues in computer-mediated communication affects decision making outcomes. By removing "irrelevant" considerations in decision making, such as status, charisma and prejudices, there may be fewer errors in judgement. For example, computer-mediated groups were relatively more task-oriented and made more solution proposals than face-to-face groups (Siegel, et al., 1986). The computer-mediated groups chose riskier alternatives and tended to display greater equality in amount of participation. If minority opinions enhance performance on specific tasks, then groups could be more effective when using computers to communicate (Kiesler, Siegel, & McGuire, 1984).

Selected Research Issues

A subset of research issues was selected for initial investigation. In the area of mode of communication, little research has been done to understand the effects of graphic communication via computer-mediation. Since military tasks are so dependent on graphic displays, it is imperative to consider the effect of graphic communication on group decision making. Consequently, a task was selected that involved both graphics and computational subtasks.

The most prevalent mode of communication in military staff tasks is voice or audio communication. Another aspect of the mode of communication issue that needs to be addressed is whether voice communication will be or should be available on a routine basis along with computer visual displays. Previous research has shown that performance is greatly affected by the presence or absence of voice communications.

A major communication system design issue is whether communications should be in real-time (synchronous) or delayed-time (asynchronous). Synchronous discussions should be better for tasks requiring more immediate responses; asynchronous discussions may facilitate longer and more deliberate exchanges. Technological communication realities must also be considered because they place definite constraints on the capabilities of both modes. There are a limited number of communication circuits available to the military unit. Although a dedicated point-to-point circuit may offer the greatest advantage for a particular task, that type of circuit may not be available. Even shared circuits have limitations. They have a capacity for a finite number of conversations, users, and data transmissions. Circuit overload or saturation will lead to communication delays and data loss.

Experimental Tasks

A specialized laboratory task was developed as a general purpose tool in which to address these specific hypotheses and, for the future, a wider range of computer-mediated, command and control issues. The essence of the task generally relates to the development of a movement plan (Dept. of the Army, 1984, 1986, 1987), performed by the operations planning cell of a division command post. The plan requires coordination among major functional staff groups, and collaboration within a single functional group. The sub-tasks included in the laboratory manifestation require: (1) route selection, and, (2) computation and creation of movement tables. A description of the task and the requirements is contained in Appendix A.

The basis for selecting this particular task for the laboratory was a belief that the task must be challenging for the military audience and at the same time be attainable, with minimum training, by a non-military audience. Additionally, this task must retain enough of a military flavor to allow acceptance when subjected to scrutiny by the Army, and it was deemed necessary that the task be map based, should rely upon graphic communications for information flow and presentation of decision alternatives, should have an element of risk in the various decision alternatives, should provide a motivation for doing well, and should have clearly defined and measurable subtasks.

The laboratory task allowed participants to be placed in different settings, depending on the mode of communication under investigation. An average of 23 minutes of interaction was required to select the shortest route satisfying a number of task requirements, (e.g., avoid engaging in battle while enroute, units will not spend more than 10 total hours on the road per day, rest stops of 20 minutes must be planned for every 3 hours of travel). The route selection task required extensive use of graphics and the solution was presented in terms of a graphic. The movement table task involved completing entries in pre-formatted tables, reflecting start and stop times, meal and rest stops, and overnight stops. A detailed description of the laboratory layout is presented in Appendix B.

"Other work" was a supplementary task. Typically other work demands came in the form of fact-based questions to emulate distractions common in the tactical staff group setting. Other work consisted of responding to task and general questions by referring to an extract of an army field manual for the answer. (An example of another work question is, "Defensible terrain affords cover and ________________.")

Figure 1 provides a flow diagram for task accomplishment. This diagram represents the task process for route selection, and is not dependent on the mode of communication used.

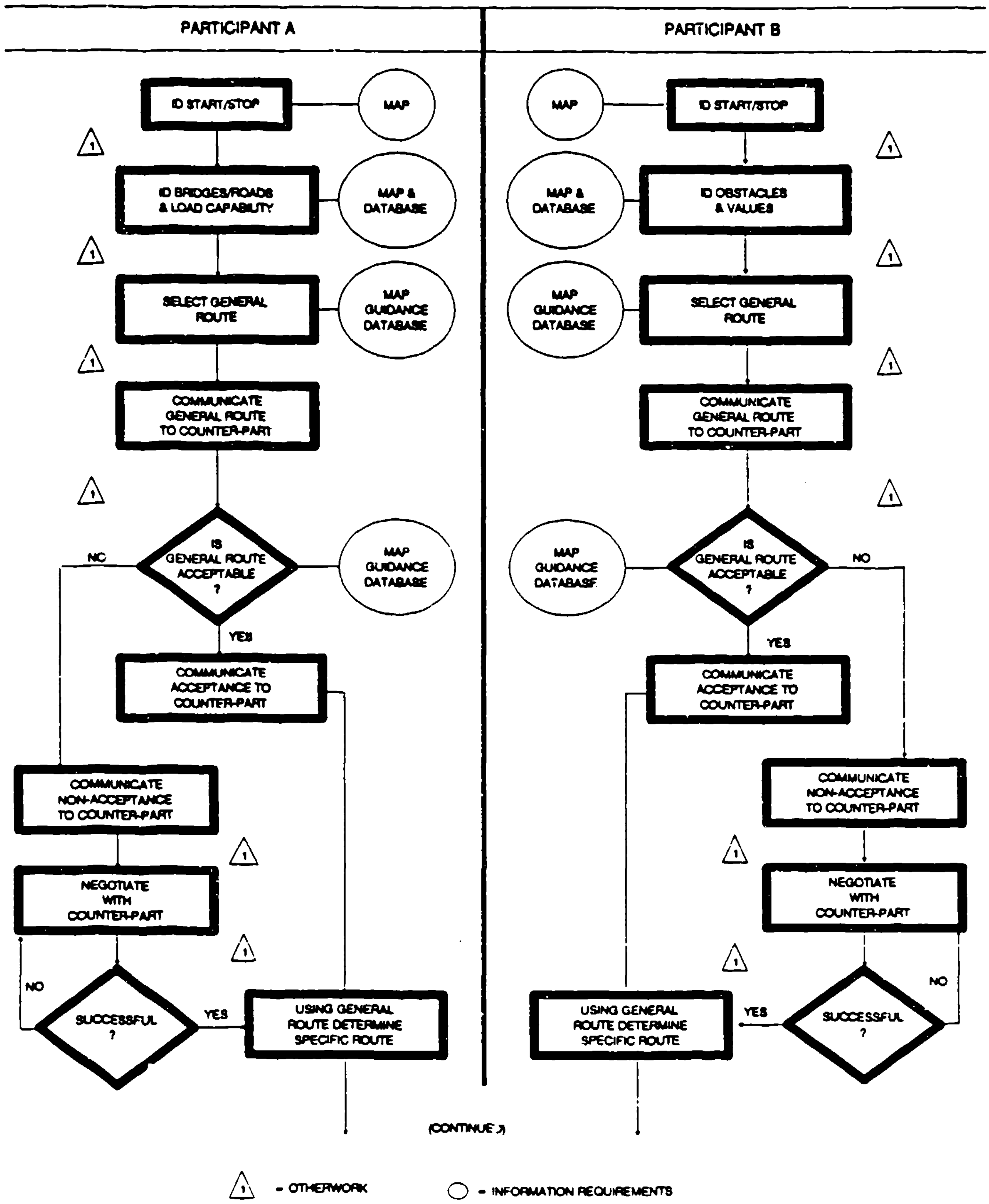

Figure 1. Task flow of route selection.

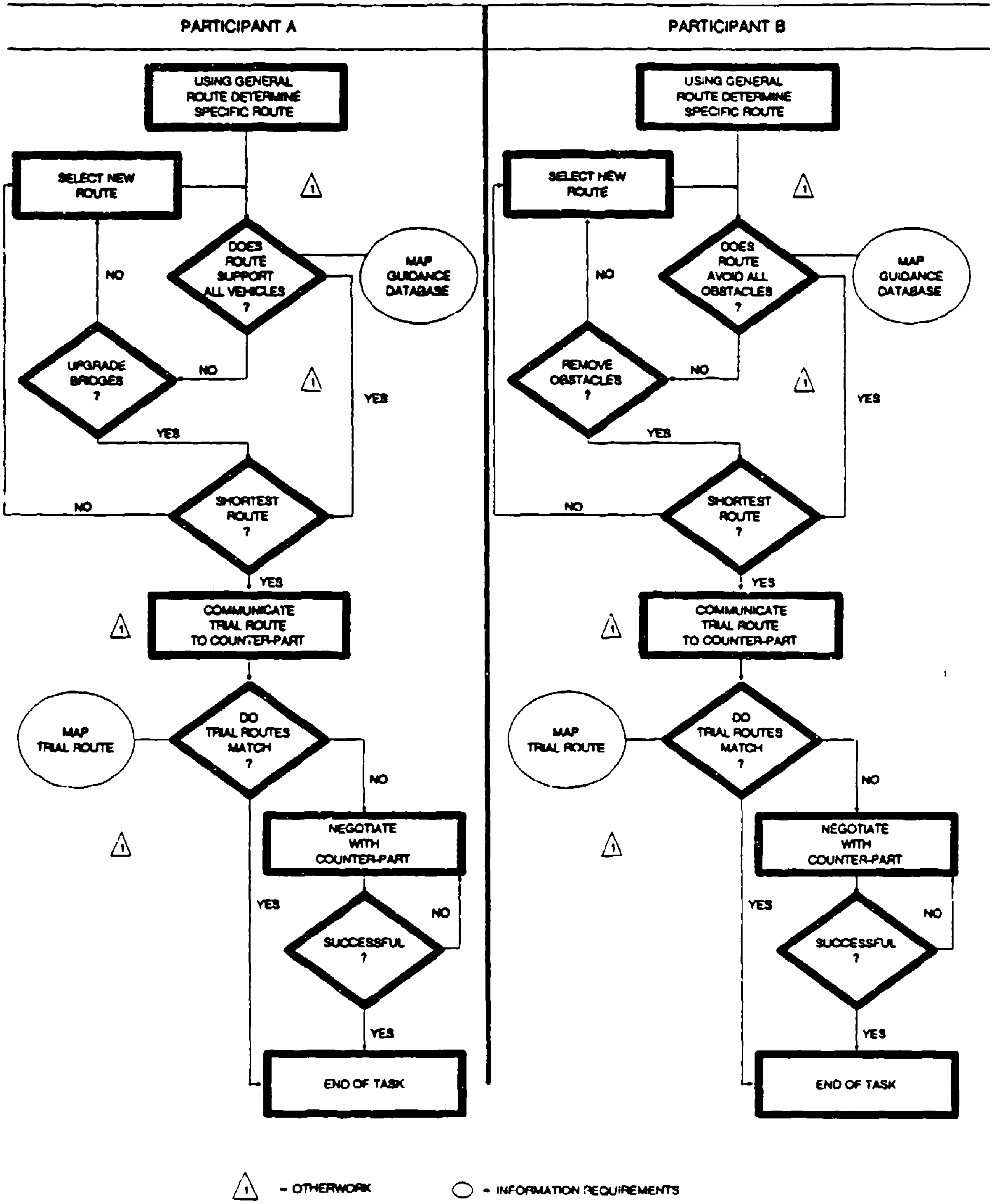

Figure 1. Task flow of route selection (continued).

Figure 2 provides a diagram of the computer programs used at the work station by the participant to solve the task. The diagram also indicates how the participant transitions from one program to another. These programs provide a vehicle for task accomplishment, communication and data collection.

DATA ENTRY. Within this program, the participant marks the start and stop of Task One and Task Two, and makes entries on the march tables for Task Two. Data Entry also is used to automatically collect time mark data when a participant leaves this program to go to MAPS or MAIL, and automatically records the return from those programs. Also collected are all entries, by time, made by the participant on the march tables, and task start and stop times. These data are then used to calculate the measures which form the dependent variables of the statistical analysis of experimental results.

MAIL. This program is used to send and receive files between participants. These files consist of messages, map slides, and march tables.

MAPS. This program allows viewing of maps, annotation of maps, creation of trial and final routes, and saving of various route versions. A separate data collection program is within MAPS that records the actions of the participant while in this program.

MESSAGE WINDOW. A "pop-up" program is available for use while in DATA ENTRY or in MAPS to read or create typed messages. The MESSAGE WINDOW has its own time log. When leaving MESSAGE WINDOW, the participant is returned to the position in the program prior to selecting the MESSAGE WINDOW.

Task time is recorded as time spent in DATA ENTRY, MAIL and MAPS. All other time is termed OTHER and may consist of MESSAGE WINDOW time, other work time, or time spent working on the task or talking to the other participant, but not in a program which is timed.

The task required little military-specific knowledge or training and was accomplished quite readily by college students. The task also satisfied experimentation requirements for measurable outputs.

To determine whether the laboratory task tapped the same sort of abilities required of staff officers, an analysis was conducted using the Job Ability Requirements Software System (JASS) (Rossmeissl, Tillman, Rigg & Best, 1983). Inspection of Table 1 shows fairly consistent matches on ability levels between the set of four staff tasks and the two experimental tasks. Thirty-three of the 42 ratings for the experimental tasks matched with one or more of the levels for the staff tasks.

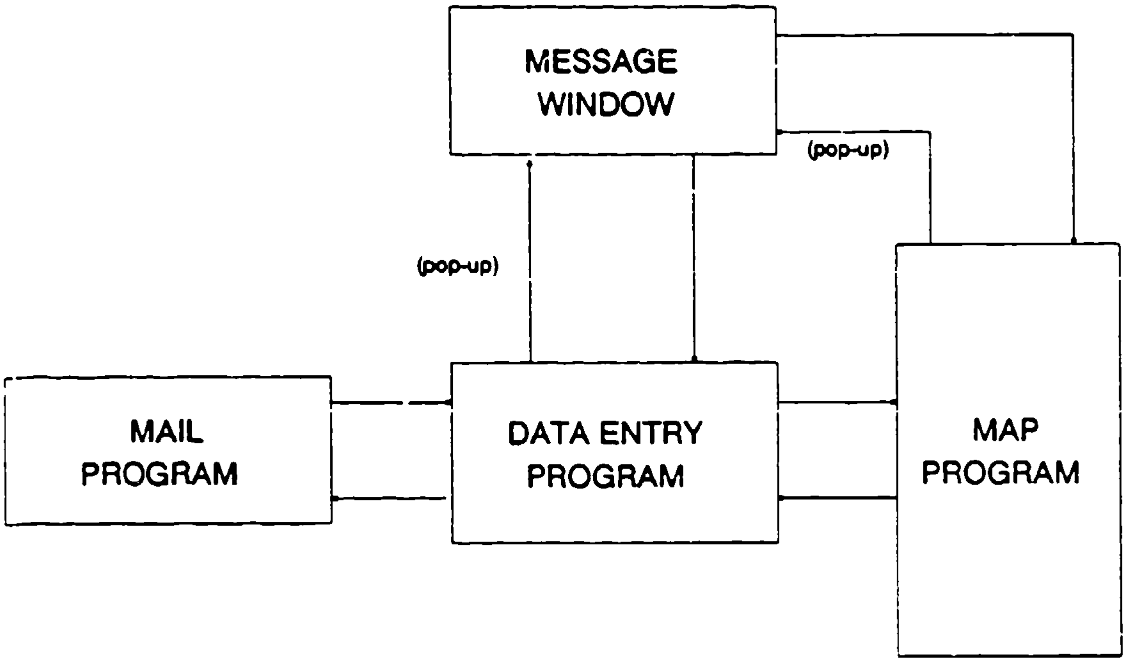

Figure 2. Task and data collection programs.

Table 1

Job Ability Requirements

Ability*		Representative Staff Tasks				Experimental Tasks	
		Operations Plan (G3)	Movement Plan (G3)	Collection Plan (G2)	Fire Support Plan	Route Selection	Movement Table
1.	Oral comprehension	H**	H	H	H	H	M
2.	Written comprehension	H	H	H	H	H	M
3.	Oral expression	H	H	H	M	M	M
4.	Written expression	H	H	H	M	M	M
5.	Memorization	M	M	M	H	M	M
6.	Problem sensitivity	M	H	M	M	M	M
7.	Originality	M	H	M	H	M	M
8.	Inductive reasoning	H	H	M	H	M	M
9.	Category flexibility	H	M	M	H	M	M
10.	Deductive reasoning	H	H	H	H	M	H
11.	Information ordering	H	H	H	H	M	H
12.	Mathematical reasoning	M	M	M	M	L	M
13.	Number flexibility	M	M	H	M	L	M
14.	Fluency of ideas	H	H	H	H	M	H
15.	Time sharing	M	H	H	H	H	M
16.	Flexibility of closure	M	H	M	H	H	H
17.	Speed of closure	-	-	-	-	-	-
18.	Selective attention	M	M	M	M	M	M
19.	Perceptual speed	H	H	M	H	M	H
20.	Spatial orientation	M	M	M	M	M	M
21.	Visualization	H	H	H	H	M	M

*FLEISHMAN JOB ABILITY TAXONOMY (Fleishman, E. and Quaintance, M., 1984).
**H = high; M = medium; L = low; - = ability not required.

Experimental Factors

Four modes of communications were examined in this investigation.

- Face-to-face. The team was collocated and used a single computer to complete the two sub-tasks.
- Synchronous computer-mediation. Two separated team members were linked through personal computers, connected by cable between RS-232 serial ports. INSYNCH software (see Appendix C) provided synchronized functions for file and screen transfer, simultaneous movement of a cursor on both screens, annotation with typed text or free-hand drawing, and a message window for typed communications. Team members were allowed to alert the other participant, by pressing a call button, when they wished to draw attention to the shared screen.

- Synchronous computer-mediation with additional voice channel. Synchronous computer-mediation was provided as above. Additionally, a push-to-talk intercom was provided the team members in lieu of a message window.

- Asynchronous computer-mediation. Physically separated team members sent and retrieved messages in the form of computer text or graphic files. Files were transmitted to a location where they were stored for access. This equated to a time-delayed mail capability with information retained indefinitely for multiple subsequent access. No voice communication was provided.

In the face-to-face mode the computer was used as a medium for task presentation. In the distributed mode of operation team members had computers with common task information. The tasks required information sharing, problem solving, and consensus.

Subjects were teamed into dyads. Each dyad performed under each of the four modes of communication. For each mode of communication, three trials of the tasks were performed. Each trial on each mode of communication used different versions of the problem. Nine versions had been prepared in advance by varying the start and stop points, the movement objectives, and the obstacles to movement. The presentation order of the modes of communication was counterbalanced, as was the order of the problems. The first trial for each mode was eliminated as a familiarization and training event. The presentation order for each dyad is shown in Table 2.

Training

The training sequence was the same for all subject dyads, as shown in Table 2. Each dyad was introduced to the requirements, provided with an explanation of the goals of the experiment, and conducted hands-on training with lab supervisor assistance and demonstration. The objectives of the training were two-fold: (1) to gain proficiency in the task requirements and (2) to gain proficiency in the required computer key strokes for the four modes. The same version of the task was used for all training sessions. At the end of the training sessions, the dyads were confident that they could accomplish the task, using any of the four modes of communication.

Table 2

Presentation Order

DYAD	ORDER OF PRESENTATION	TRIAL/ VERSION	TRIAL/ VERSION	DYAD	ORDER OF PRESENTATION	TRIAL/ VERSION	TRIAL/ VERSION
A	FACE-TO-FACE	0/T*		F	FACE-TO-FACE	0/T	
	SYNCH + VOICE	0/T			SYNCH + VOICE	0/T	
	SYNCH-VOICE	0/T			SYNCH-VOICE	0/T	
	ASYNCH	0/T			ASYNCH	0/T	
	ASYNCH	1/8	2/1		SYNCH + VOICE	1/1	2/8
	SYNCH + VOICE	1/6	2/5		FACE-TO-FACE	1/8	2/6
	SYNCH-VOICE	1/2	2/3		SYNCH-VOICE	1/2	2/7
	FACE-TO-FACE	1/7	2/4		ASYNCH	1/3	2/4
B	FACE-TO-FACE	0/T		G	FACE-TO-FACE	0/T	
	SYNCH + VOICE	0/T			SYNCH + VOICE	0/T	
	SYNCH-VOICE	0/T			SYNCH-VOICE	0/T	
	ASYNCH	0/T			ASYNCH	0/T	
	SYNCH-VOICE	1/5	2/8		SYNCH-VOICE	1/8	2/7
	ASYNCH	1/3	2/6		SYNCH + VOICE	1/4	2/5
	SYNCH + VOICE	1/4	2/7		FACE-TO-FACE	1/2	2/1
	FACE-TO-FACE	1/2	2/1		ASYNCH	1/3	2/6
C	FACE-TO-FACE	0/T		H	FACE-TO-FACE	0/T	
	SYNCH + VOICE	0/T			SYNCH + VOICE	0/T	
	SYNCH-VOICE	0/T			SYNCH-VOICE	0/T	
	ASYNCH	0/T			ASYNCH	0/T	
	SYNCH-VOICE	1/1	2/3		FACE-TO-FACE	1/6	2/8
	ASYNCH	1/2	2/8		SYNCH + VOICE	1/1	2/3
	FACE-TO-FACE	1/7	2/5		ASYNCH	1/4	2/7
	SYNCH + VOICE	1/6	2/4		SYNCH-VOICE	1/5	2/2
D	FACE-TO-FACE	0/T		I	FACE-TO-FACE	0/T	
	SYNCH + VOICE	0/T			SYNCH + VOICE	0/T	
	SYNCH-VOICE	0/T			SYNCH-VOICE	0/T	
	ASYNCH	0/T			ASYNCH	0/T	
	SYNCH-VOICE	1/7	2/3		FACE-TO-FACE	1/7	2/5
	FACE-TO-FACE	1/4	2/8		ASYNCH	1/2	2/4
	ASYNCH	1/5	2/6		SYNCH + VOICE	1/6	2/1
	SYNCH + VOICE	1/2	2/1		SYNCH-VOICE	1/8	2/3

*0/T represents a training trial, which was identical for all dyads.

Test Participants

All subjects were male college undergraduates. Their participation in the experiment was voluntary; however, they were paid a nominal amount for participating.

Each subject provided information regarding their background that could be related to the experimental task. These data are summarized in Table 3. Experience is self-rated. Military experience includes active duty, reserve duty, and ROTC. Map Reading experience means the subject had some formal or informal experience using maps. Prior use of computers ranges from 1, no experience, to 6, extensive use. Communication experience means that the subject has used inter-computer communications. Although not specifically queried, it was observed that typing skills ranged from proficient to "hunt and peck." The lack of typing skills did not appear to have a pronounced effect on task accomplishment.

Table 3

Task-Related Experience for Dyads

		Map-Task Experience		Computer Experience	
Dyad	Subject	Military	MapReading	PriorUse	Communication
A	A	no	yes	6	yes
	B	no	yes	2	no
B	A	yes	yes	4	yes
	B	yes	yes	3.5	no
C	A	yes	yes	4	yes
	B	no	no	1	no
D	A	no	no	2	no
	B	no	no	3	yes
F	A	yes	yes	5	yes
	B	yes	yes	7	yes
G	A	yes	yes	1	no
	B	no	yes	2	no
H	A	no	yes	5.5	yes
	B	no	no	6	no
I	A	no	yes	5	yes
	B	no	yes	7	yes

Data Sources

The experimental task provided a rich source of data, including event time logs, route score, voice transcripts, number of units of "other work" completed, participant questionnaire ratings on types of problems and design features, and observations of the experiment leader.

Measures

The measures examined dealt with the recording of events and time that were available for measurement and with the coding applied to the transcripts of the communications. These measures are discussed below:

Task Measures

Route ID Time. This measure portrays the total time necessary for the completion of the graphical task. The total time consists of the time elements: MAPS, MAIL, DATA ENTRY, and OTHER.

Table Time. This measure portrays the total time necessary for the completion of the data entry task. The total time consists of the time elements: MAPS, MAIL, DATA ENTRY, and OTHER.

Other Work. The accomplishment of other work is shown as the number of other work items that can be completed per unit time (1 hour). Other work consisted of fact-based tasks and general knowledge questions and served as a secondary task measure of performance.

Route Score. A set of penalties was developed to allow a comparative solution value to be determined for each route determined for the Route ID Task trials. This route score allows comparison of solutions across modes. The penalties are described in Appendix A, Page A-4.

Route Agreement Time. The elapsed time until the two participants have come to an agreement on the selected route and have annotated the computer map sheet with the route, bridges upgraded or driven through, and with the obstacles driven through or removed. Once the preceding steps are accomplished the map is saved as a final map. This data point, although comparable for all dyads, is affected by the amount and mode of communication. This time is common, measurable and comparable across modes.

Figure 3 shows the relationship of the time measures collected during the laboratory sessions.

Transcript Analysis Measures

Transcripts for the voiceless modes, Synch-V and Asynch, were obtained from typed messages sent between team members over the computer network. Transcripts from the two voice modes were taken from audio tape recordings of team members while they performed the experimental tasks. One transcript consisted of all communication that occurred during Route ID Time and Table Time for a given mode and trial. Each

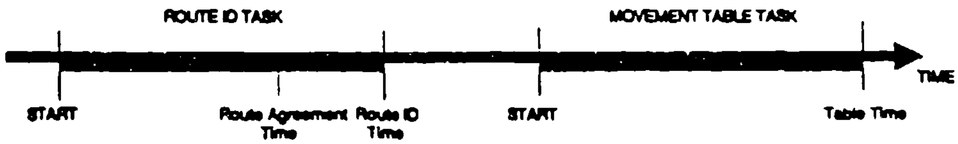

Figure 3. Relationship of time measures.

dyad participated in four modes of two trials each; resulting in a total of 64 transcripts (4 modes * 2 trials * 8 dyads).

A number of dependent variables were identified for possible analysis. The variables were grouped into four categories for descriptive purposes. Transcript data were taken from the output of the transcript analysis program, SALT (Miller & Chapman, 1985). Content codes were added to each message by the experiment leader before the analysis. This coding allowed several language characteristics to be examined and analyzed. The codes are described below.

Sentence. These variables identified the basic structure of each message or sentence. The three sentence variables are:

[COMPLT] number of complete sentences
[INCOMP] number of incomplete sentences
[FLSTRT] number of false starts: "I think, I think I'll ..."

Style. The five variables in this category indicated the type of message. They are:

[DECLAR] percentage of declarative sentences
[QUEST] percentage of questions
[EXCLAM] percentage of exclamatory sentences
[UNFIN] percentage of unfinished sentences
[INTRPT] percentage of interrupted sentences

Content. Fifteen variables were used to describe the content of each message. Some refer to an entire message and others refer to particular words. More than one code could be assigned to a word. They are:

[A] abbreviation understandable in context: obs for obstacles
[C] message indicated confusion on part of sender
[CR] computer-related message: "Hit return key."
[EM] end-of-message (non-voice mode specific)
[F] feedback from message receiver to sender: "okay."

[GE]	grammatical error
[GI]	general instructions: "You enter the data."
[NTO]	non-task oriented message: "It's hot today."
[P]	processing: "I'll figure the times now."
[PO]	polite: "Thank you."
[SP]	spelling error
[TO]	task oriented message: "Take hwy 12 South."
[TS]	task specific word: "serial"
[U]	uninhibited language: "That was stupid!"
[?]	transcriber uncertain about message content

Word. These variables captured the usage of words alone and within messages. The six word variables are:

[DIFFW]	number of different words used
[TOTW]	total number of words used
[TTR]	type-token ratio (index of vocabulary diversity)
[MLM]	mean length of each message
[WDS/M]	number of words per minute
[MSG/M]	number of messages per minute

The data were analyzed in two parts. First, an overall analysis of the task and transcript data was performed. Next, comparisons for the FTF mode to the other modes were performed for the task and transcript data. A completely within subjects (dyads) repeated measures design was used to analyze the data. The repeated within group factors (fixed effects) were trials and communication modes. There were eight two-person dyads with two trials per dyad. The four communication modes that each dyad participated in were:

(1) face-to-face voice dialogue (FTF),
(2) synchronous voice and computer dialogue (Synch + V),
(3) synchronous computer dialogue (Synch-V), and
(4) asynchronous computer dialogue (Asynch).

The dependent variables for each mode were:

(1) Route ID Time,
(2) Table Time,
(3) Route Agreement Time,
(4) Route Score, and
(5) mean number of pieces of Other Work.

Overall Task Analysis

The means and standard deviations, averaged across Trials 1 and 2 dependent variables, are shown in Table 4 by Communication Mode. The data for each dependent variable for Communication Mode and Trial are reported in Appendix D along with the statistical analysis summary tables. Box plots of the dependent variables are in Appendix E. Multivariate Wilk's lambda statistics are reported, except for Trials main effects, which are reported as univariate statistics.

Table 4

Mean Scores and Standard Deviations by Communication Mode Averaged Over Trials for Each Dependent Variable

	MODE			
	FTF	Synch + V	Synch-V	Asynch
Route ID Time				
Mean	1059.375	1094.938	2396.625	5317.688
Standard deviation	241.167	266.647	850.685	1188.878
Table Time				
Mean	1735.438	1803.625	2782.625	4657.688
Standard deviation	429.126	190.738	927.106	1814.390
Route Agreement Time				
Mean	569.875	561.625	1324.313	3031.313
Standard deviation	111.498	182.427	412.796	617.528
Route Score				
Mean	-2.563	-3.063	-4.563	-3.563
Standard deviation	0.417	1.178	1.741	1.720
Other Work				
Mean	64.313	64.750	28.938	75.563
Standard deviation	42.933	32.984	18.329	25.137

The Trials by Modes interaction was significant for Route Agreement Time, $\underline{F}(3,5) = 7.2$, $\underline{p} = .029$. As shown in Appendix D, in the Synch + V condition, Route Agreement Time was lower on Trial 1 than it was on Trial 2. None of the Trials by Modes interactions for the remaining dependent variables were significant. There was an overall effect of Trials for Route ID Time, $\underline{F}(1,7) = 10.6$, $\underline{p} = .014$, and Route Agreement Time, $\underline{F}(1,7) = 5.9$, $\underline{p} = .046$. In these cases, time measures were lower for the second trial. The main effect of trials was not significant for any of the remaining dependent variables.

Communication Mode was significant for Route ID Time, $\underline{F}(3,5) = 54.3$, $\underline{p} < .001$; for Table Time, $\underline{F}(3,5) = 13.8$, $\underline{p} < .001$; for Route Agreement Time, $\underline{F}(3,5) = 76.2$, $\underline{p} < .001$; and for Other Work, $\underline{F}(3,5) = 11.7$, $\underline{p} = .011$. Values for Route Score were not significant and are not discussed further. Communication Mode is analyzed in detail below. In general, times increased as the mode became less "conversational;" i.e., from FTF to Asynch, as can be seen in Table 4 and in Figures 4 and 5. Mean values for Route ID Time and Table Time are plotted in Figure 4 (the measures are shown as ID

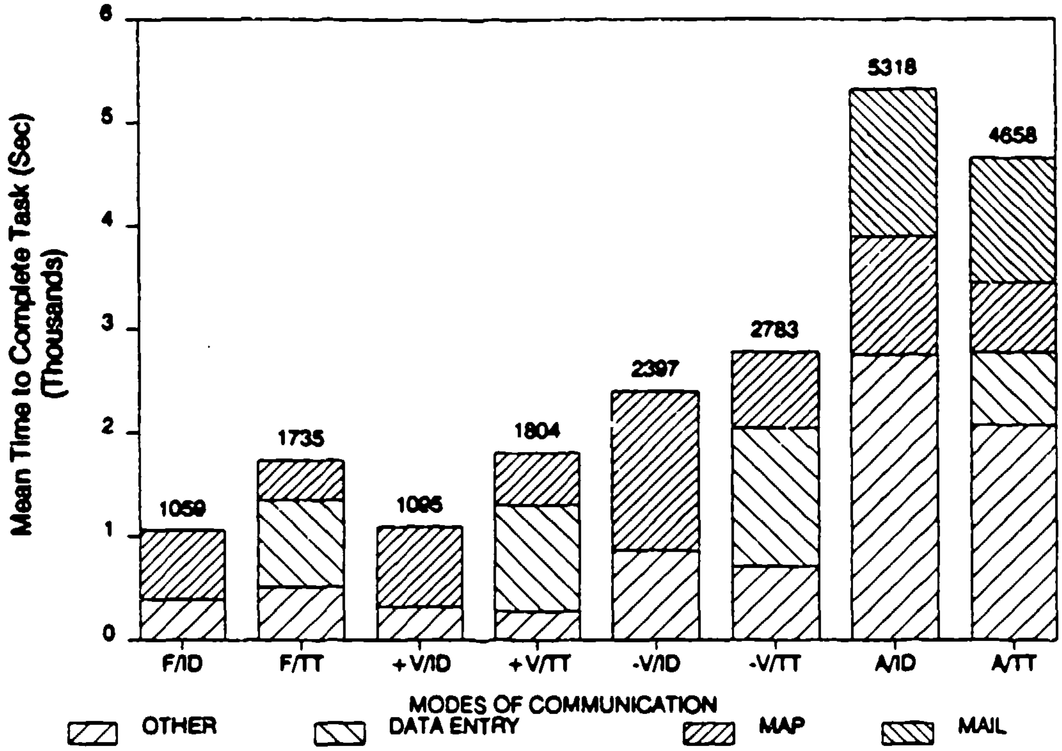

Figure 4. Mean time to complete task by modes of communication and task.

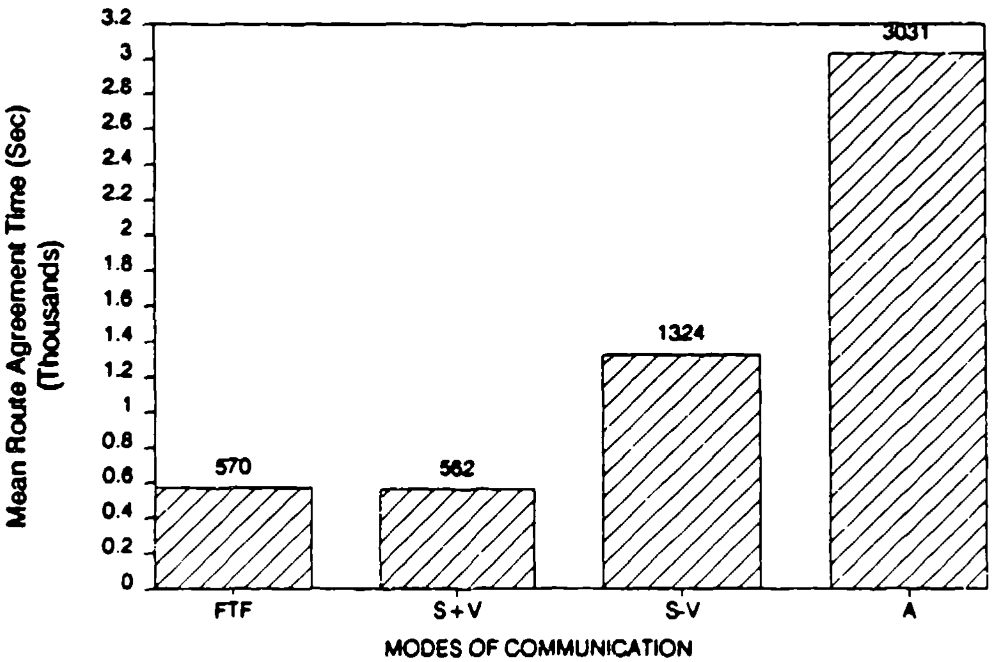

Figure 5. Mean route agreement time by modes of communication.

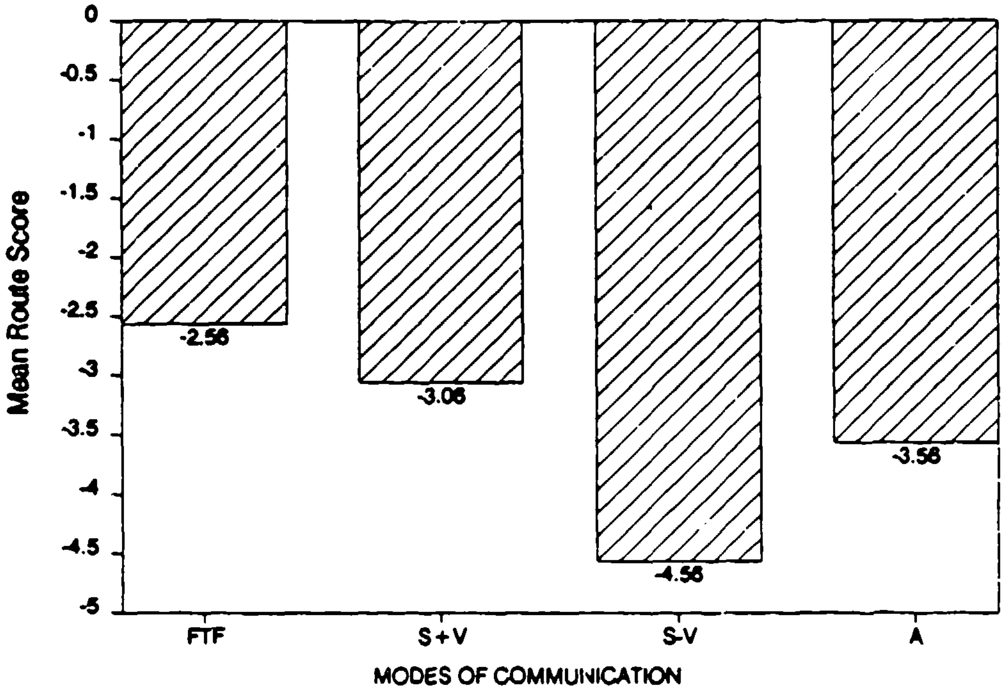

Figure 6. Mean route score by communication mode.

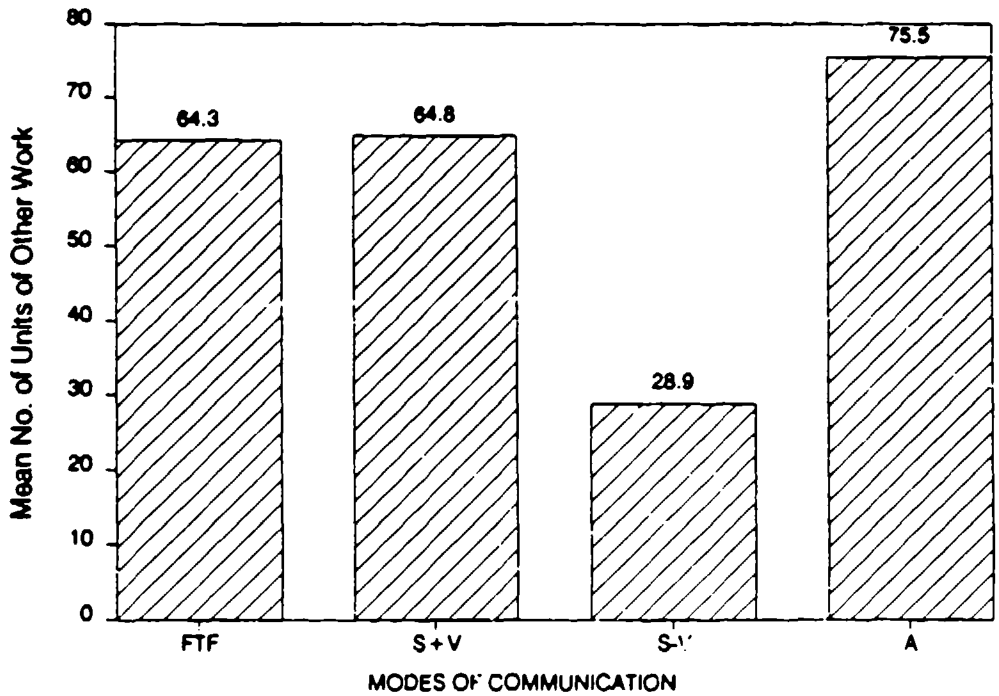

Figure 7. Mean units of other work per hour by communication modes.

and TT, respectively). Mean values for Route Agreement Time are plotted in Figure 5, mean Route Score values are plotted in Figure 6, and mean values for Other Work are plotted in Figure 7.

Communication Mode Analysis of Task Variables

The main purpose of this experiment was to study the effects of communication modes on task performance. To accomplish this goal *a priori* comparisons of the FTF mode to the other three modes were performed. The contrasts were:

(a) FTF versus Synch + V,
(b) FTF versus Synch-V, and
(c) FTF versus Asynch.

The source tables for this analysis are in Appendix F. Means and standard deviations are in Table 4, and the significant effects are summarized in Table 5.

Table 5

Significant Comparisons of Communication Modes for Task Data

	Comparison of FTF to		
	Synch + V	Synch-V	Asynch
Route ID Time		$F(1,7) = 18.1, p = .004$	$F(1,7) = 103.4, p = < .001$
Table Time		$F(1,7) = 10.6, p = .014$	$F(1,7) = 26.1, p = .007$
Route Agreement Time		$F(1,7) = 26.2, p = .001$	$F(1,7) = 127.4, p < .001$
Route Score		$F(1,7) = 8.8, p = .021$	
Other Work		$F(1,7) = 6.3, p = .041$	

Comparison of FTF to Synch + V. As predicted, there were not any differences between the FTF mode and the Synch + V mode (see Table 5).

Comparison of FTF to Synch-V. Significant performance differences occurred between FTF and Synch-V on Route ID Time, Table Time, Route Agreement Time, Route Score, and Other Work, as shown in Table 5. Route ID Time and Table Time took longer in the Synchronous-Voice mode than it did in the Face-To-Face mode. This can be seen in Figure 4. This was also true for Route Agreement Time, which can be seen in Figure 5. Performance, as indicated by Route Score, was lower in the Synch-V condition than in the FTF condition. This is shown in Figure 6. Other Work occurred at a slower rate, as shown in Figure 7.

Comparison of FTF to Asynch. There were significant performance differences between FTF and Asynch for Route ID Time and Table Time (see Table 5 and Figure 4), and for Route Agreement Time (see Table 5 and Figure 5). It can be seen in Table 4 and Figures 4 and 5 that times in the Asynchronous mode were much longer than times in the Face-to-Face mode.

Overall Transcript Analysis

Transcripts oi communications between dyad members were analyzed using analysis of variance (ANOVA). The independent variables were trials and communication mode. The variables [CR], [EM], [FLSTRT], [INCOMP], [INTRPT], [NTO], [SP], [TTR], [UNFIN], and [?] were excluded from the ANOVAs because they did not occur in some of the experimental conditions. Feedback [F] was excluded from the ANOVA because it rarely occurred in the Asynch condition. Mode comparisons of this code were analyzed with t-tests.

Means and Standard Deviations (SDev) for the transcript data are presented in Table 6. The results are discussed by sentence, style, content and word categories. Complete ANOVA source tables are in Appendix G. All $\underline{F}$ values are univariate. Significant differences among the modes are discussed later under the section, Communication Mode Analysis.

Table 6.

Means & Standard Deviations for Each Transcript Variable by Communication Mode.

		FTF		Synch + V		Synch-V		Asynch	
		Mean	SDev	Mean	SDev	Mean	SDev	Mean	SDev
Sentence									
*	[COMPLT]	223.1	136.8	136.4	50.6	61.1	18.6	35.4	15.3
	[INCOMP]	18.0	11.0	2.5	2.2	.1	.2	-	-
	[FLSTRT]	2.1	2.3	1.5	1.6	.2	.3	-	-
Style									
m	[DECLAR]	72.9	3.8	74.8	4.7	74.8	9.3	86.5	12.8
*	[QUEST]	19.3	2.9	23.3	5.0	24.0	8.6	7.7	4.5
	[EXCLAM]	.2	.4	.4	.8	.9	1.1	.8	.8
	[UNFIN]	4.7	2.7	1.6	1.3	.2	.4	-	-
	[INTRPT]	2.7	1.5	.0	.1	-	-	-	-
Content									
*	[A]	1.8	1.6	.5	.4	7.9	4.1	6.4	5.3
*	[C]	11.6	10.4	4.1	2.7	2.2	1.2	.8	1.1
	[CR]	7.3	8.2	4.9	4.1	2.3	2.4	-	-
	[EM]	-	-	-	-	1.3	3.5	.3	.9
	[F]	26.1	17.7	18.8	12.7	8.3	4.6	.3	.4
	[GE]	.8	1.0	.9	.8	.8	.9	.7	.6
m	[GI]	51.2	47.5	24.4	14.6	8.6	6.8	7.3	3.6
	[NTO]	3.2	2.5	1.1	2.2	1.3	2.8	-	-
	[P]	18.9	12.6	18.5	7.8	14.6	7.4	12.6	3.7
	[PO]	.7	.4	1.3	1.3	1.3	1.2	.4	.6
	[SP]	-	-	.2	.3	3.8	2.9	3.2	3.1
*	[TO]	99.1	47.4	53.9	22.8	23.9	6.5	16.9	7.5
m	[TS]	91.6	39.5	70.4	36.6	55.3	15.8	61.9	23.4
m	[U]	4.6	4.0	2.3	3.2	1.5	1.1	.5	.8
	[?]	2.5	3.0	1.0	.7	.1	.2	-	-
Word									
*	[DIFFW]	280.1	73.4	229.1	38.7	180.3	33.8	161.6	62.2
*	[TOTW]	1158.9	612.5	825.9	334.4	452.6	107.9	395.8	196.6
	[TTR]	.4	.0	.4	.0	.4	.1	.4	.1
*	[MLM]	5.0	.7	6.0	1.2	7.6	1.2	11.0	1.8
m	[WDS/M]	22.8	15.6	17.4	11.3	5.6	2.7	4.5	4.4
*	[MSG/M]	5.3	3.4	2.9	1.8	.8	.5	.4	.4

Note. '*' indicates variables where significant differences were found in the overall and mode comparisons and 'm' indicates differences found in mode comparisons only.

Sentence. Overall, there were differences among Communication Modes for the number of complete sentences, $F(3,5) = 10.3$, $p = .01$. The Trials and Trials by Modes effects were not significant. The FTF mode tended to produce the most sentences. This can be seen in Table 6 and Figure 8.

Style. Only the percentage of questions varied significantly between modes, $F(3,5) = 87.9$, $p < .001$. None of the Trials or Trials by Modes effects were significant for any of the Style variables. Mean percentages are plotted in Figure 9.

Content. Of the nine Content codes that were analyzed, only the number of abbreviations, [A], confusion, [C], and task oriented [TO] messages showed significant differences between communication mode. They were $F(3,5) = 8.8$, $p = .02$ for [A], $F(3,5) = 10.4$, $p = .01$ for [C]; and $F(3,5) = 12.8$, $p = .01$ for [TO]. Again, none of the Trials effects or Trials by Modes interactions were significant. Means of [A], [TO], and [C] are plotted in Figures 10, 11 and 16, respectively.

Word. All of the word variables that were analyzed showed significant differences across communication modes except for the number of words per message, WDS/M. The results are $F(3,5) = 6.6$, $p = .03$ for DIFFW, $F(3,5) = 5.7$, $p = .05$ for TOTW, $F(3,5) = 22.2$, $p .001$ for MLM, and $F(3,5) = 9.2$, $p = .02$ for MSG/M. The differences across modes can be seen in Figure 12, for the mean number of different words; Figure 13, for the mean total number of words used; Figure 14, for the mean length of each message; and in Figure 15, for the mean number of messages per minute. These differences are discussed in detail below.

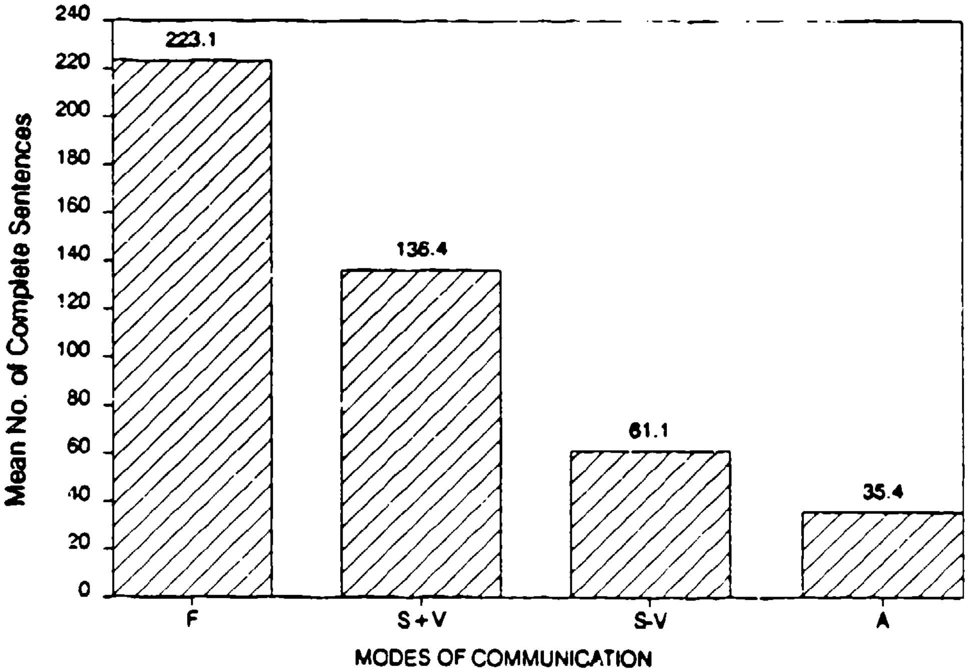

Figure 8. Mean number of complete [COMPL] sentences by communication modes.

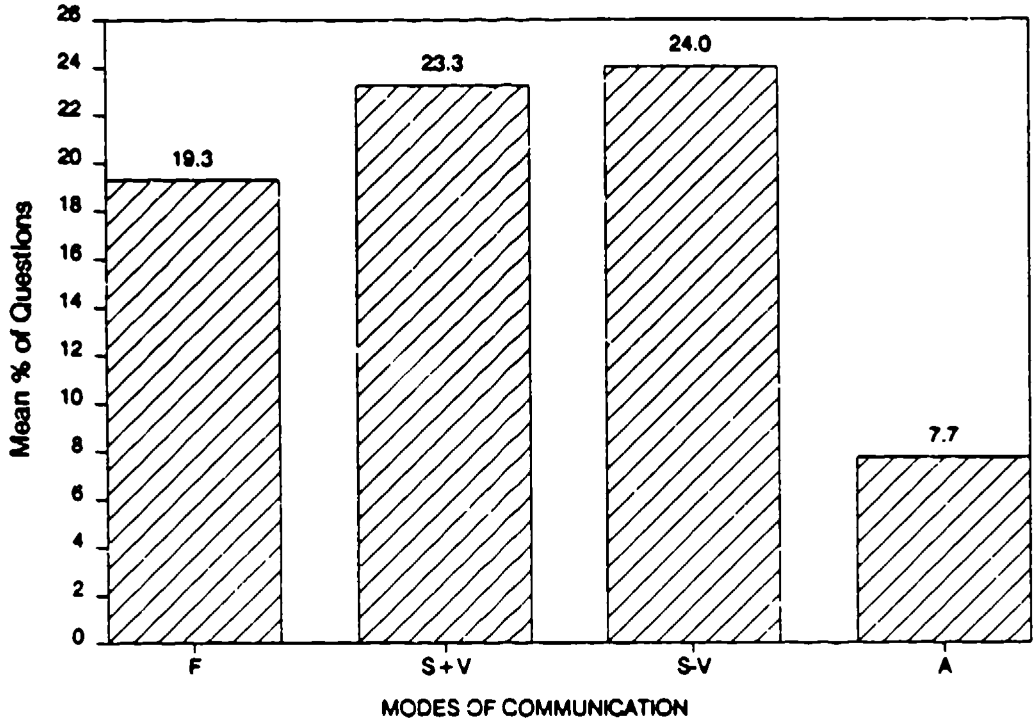

Figure 9. Mean percentage of questions [QUEST] by communication modes.

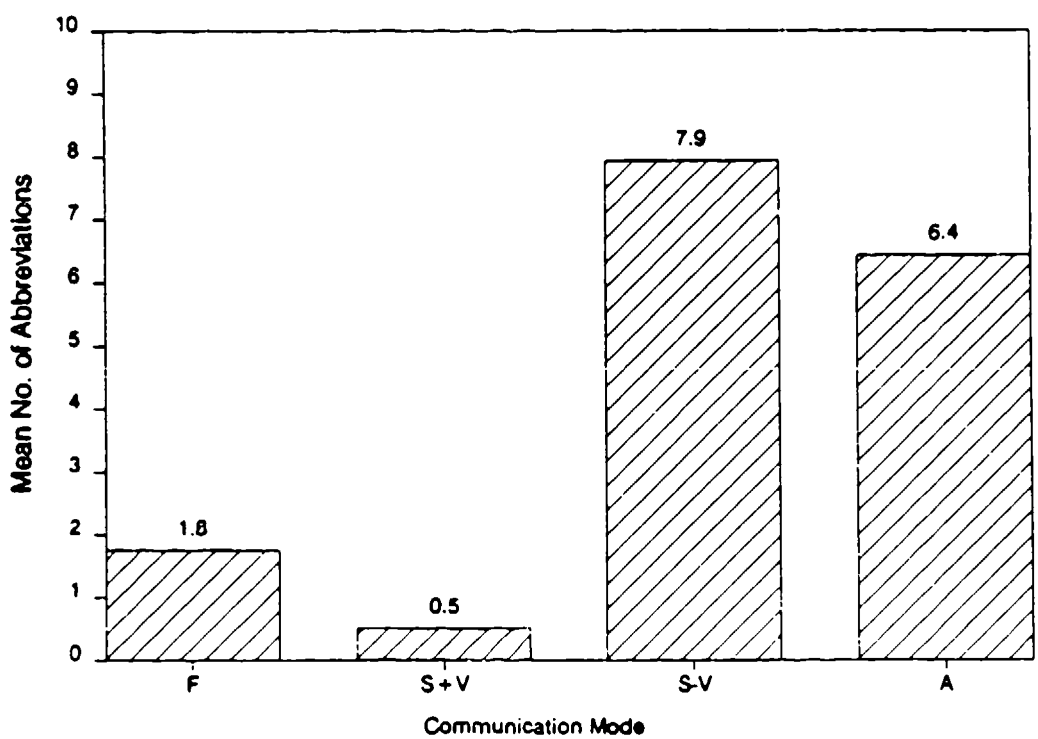

Figure 10. Mean number of abbreviations [A] used by communication mode.

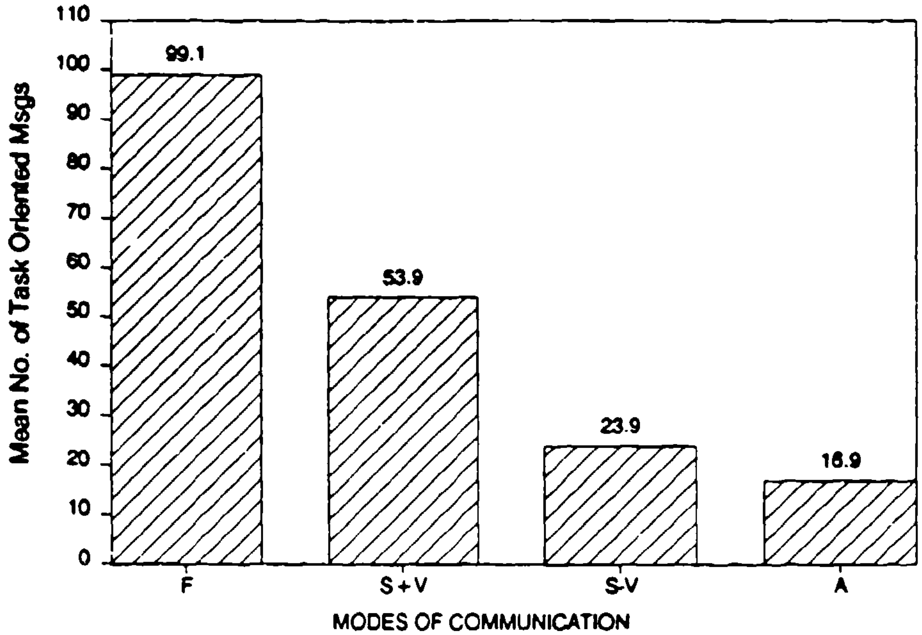

Figure 11. Mean number of task oriented [TO] messages by communication mode.

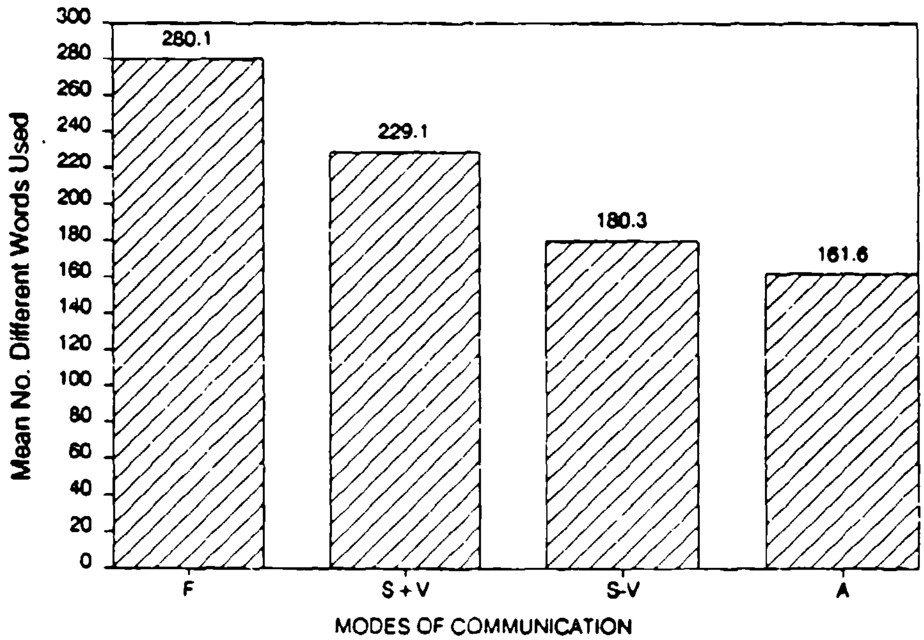

Figure 12. Mean number of different words [DIFFW] used by communication modes.

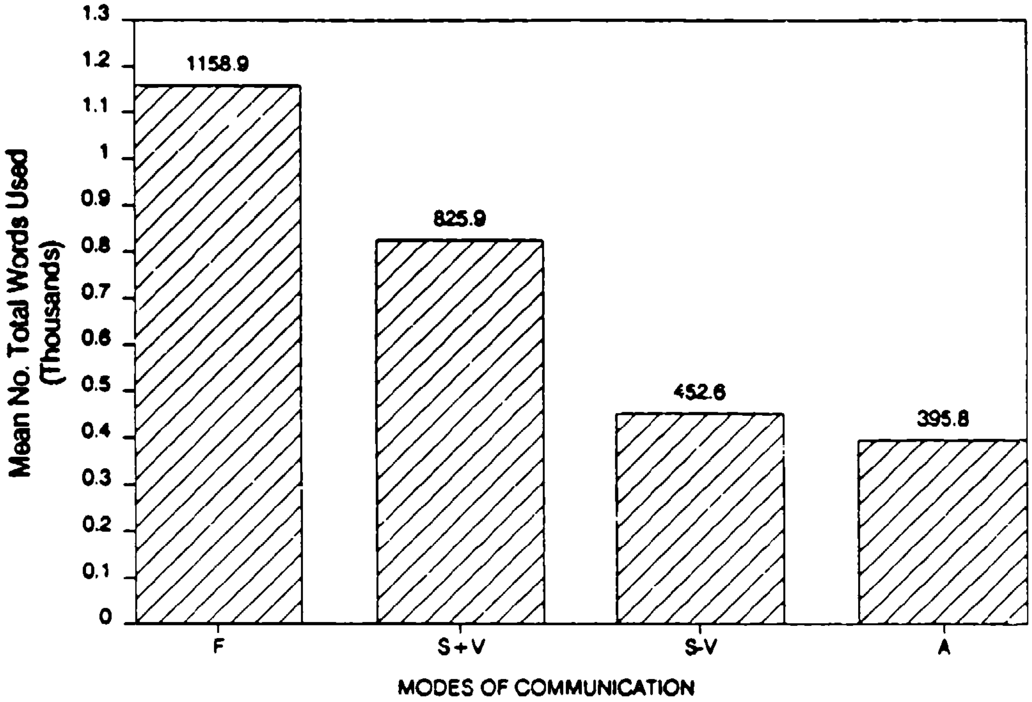

Figure 13. Mean total number of words [TOTW] used by communication modes.

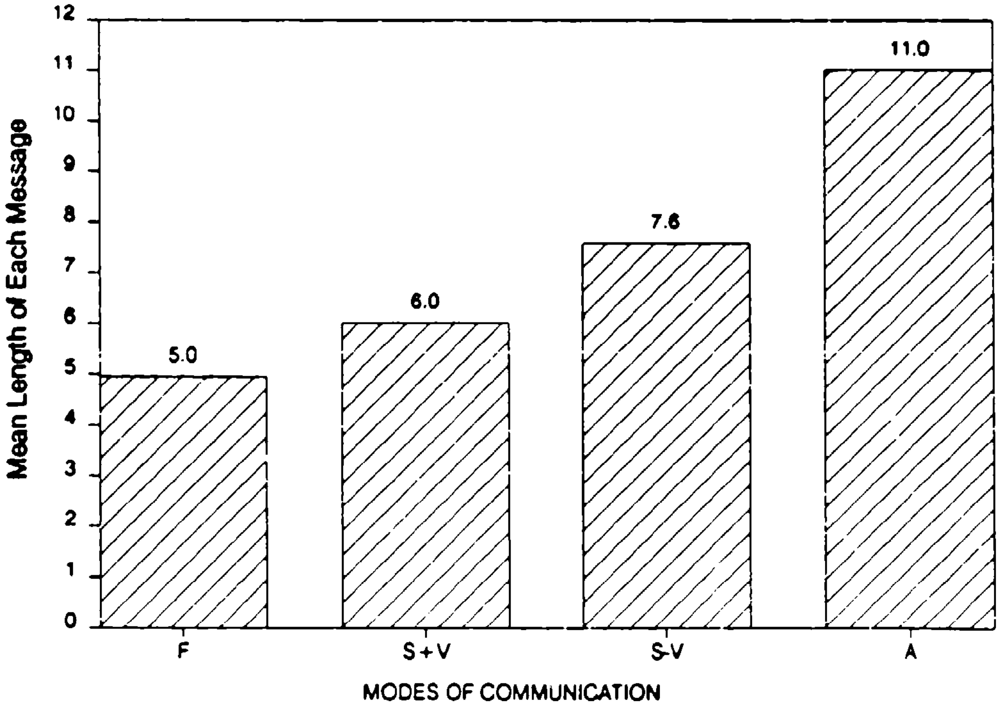

Figure 14. Mean Length of each message [MLM] by communication modes.

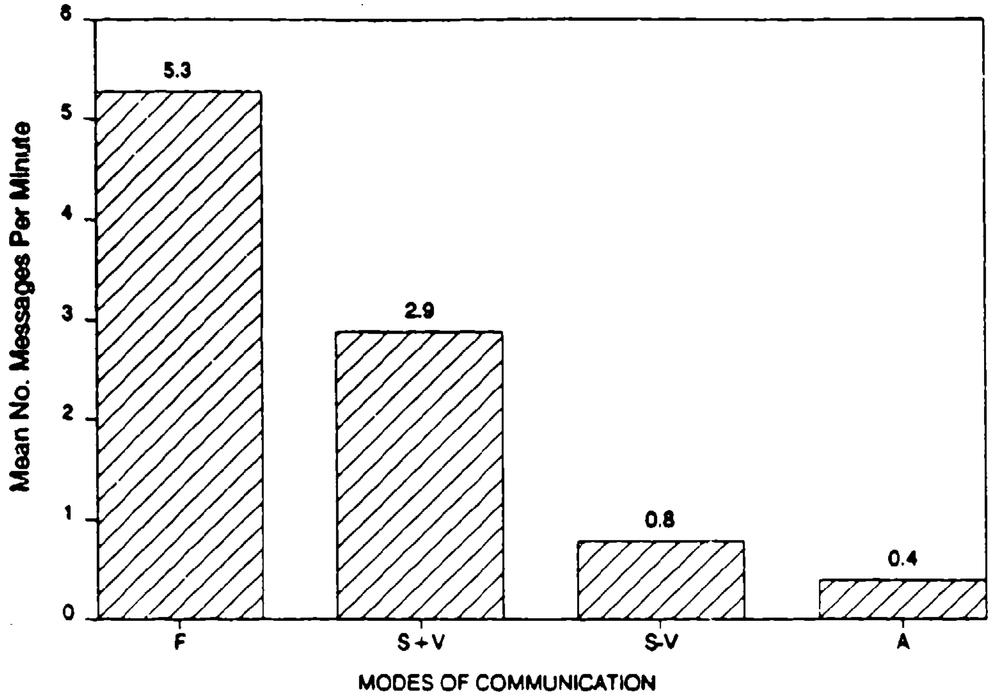

Figure 15. Mean number of messages per minute [MSG/M] by communication modes.

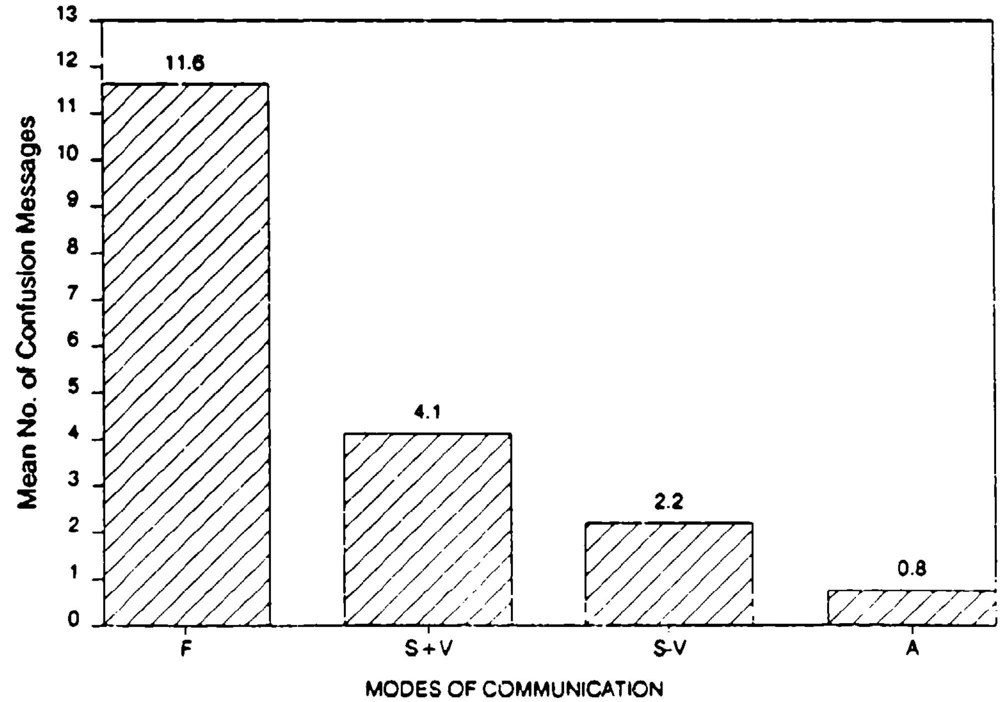

Figure 16. Mean number of Confusion [C] messages by communication modes.

Communication Mode Analysis of Transcript Variables

The same *a priori* comparisons of the FTF mode to the other modes were performed on the transcript variables. Significant mode comparison effects are summarized in Table 7. Comparisons on Feedback [F] were made using t-tests. FTF tended to produce more Feedback than the other modes, but the only significant effect, using Bonferroni's alpha adjustment, was the FTF versus Asynch comparison.

Table 7

Significant Comparisons of Communication Modes for Transcript Data

	Comparison of FTF to		
	Synch + V	Synch-V	Asynch
Sentence			
[COMPLT]		$F(1,7) = 10.5, p = .01$	$F(1,7) = 15.4, p = .01$
Style			
[DECLAR]			$F(1,7) = 12.2, p = .01$
[QUEST]			$F(1,7) = 53.4, p < .001$
Content			
[A]	$F(1,7) = 5.7, p = .01$	$F(1,7) = 15.2, p = .01$	
[C]		$F(1,7) = 7.1, p = .03$	$F(1,7) = 8.6, p = .02$
[F]			$F(7) = 4.1, p = .004$
[GI]		$F(1,7) = 6.1, p = .04$	$F(1,7) = 6.5, p = .04$
[TO]	$F(1,7) = 5.6, p = .05$	$F(1,7) = 20.9, p < .001$	$F(1,7) = 25.2, p < .001$
[TS]		$F(1,7) = 8.1, p = .03$	
[U]	$F(1,7) = 6.4, p = .04$	$F(1,7) = 6.5, p = .04$	$F(1,7) = 7.8, p = .03$
Word			
[DIFFW]		$F(1,7) = 13.9, p = .01$	$F(1,7) = 14.8, p = .01$
[TOTW]		$F(1,7) = 10.7, p = .01$	$F(1,7) = 11.9, p = .01$
[MLM]		$F(1,7) = 17.7, p < .001$	$F(1,7) = 87.8, p < .001$
[WDS/M]		$F(1,7) = 7.9, p = .03$	$F(1,7) = 9.9, p = .02$
[MSG/M]		$F(1,7) = 12.2, p = .01$	$F(1,7) = 16.3, p < .001$

Comparison of FTF to Synch + V. Three Content codes, [A], [TO], and [U], showed significant differences between these two modes (see Table 7). More abbreviations, task oriented messages, and uninhibited words were used in FTF as compared to Synch + V. None of the Sentence, Style, or Word variables reached significance on this comparison.

Comparison of FTF to Synch-V. This comparison revealed significant differences on all those variables indicated in Table 7. There were more complete sentences in the FTF mode than there were in Synch-V. Content codes [A], [C], [GI], [TO], [TS], and [U] produced significant effects. Many more abbreviations were used in the Synch-V mode when compared to the FTF mode. For the remaining codes, FTF values were larger than those found in Synch-V.

Comparison of FTF to Asynch. As before, there were more complete sentences in FTF than in Asynch. This leads to FTF values that were larger than corresponding Asynch values. One deviation from this trend was the lower percentage of declarative sentences in FTF than in Asynch.

Questionnaire Analysis

Data were also collected in the form of a questionnaire completed by the participants after completing the last laboratory session. This information is presented in Table 8. The participants were asked to rate the attributes of the Route Identification Task, Movement Table Task, and Other Work. The attributes were presented on a scale of 1-7. The four attribute pairs were the same for the three categories. The attribute pairs were: DIFFICULT/EASY, EXCITING/BORING, SIMPLE/COMPLEX, and FRUSTRATING/MOTIVATING. Using a scale from 1 for "very uncomfortable" to 7 for "very comfortable", the participants rated the experiment a mean of 5.6. They were also asked to rank the four modes of communication in terms of desirability. Sign tests indicated that the rank ordering of modes, from most to least desirable, was FTF, Synch + V, Synch-V, and Asynch.

Table 8

Questionnaire Data

	Difficult(1) Easy(7)	Exciting(1) Boring(7)	Simple(1) Complex(7)	Frustrating(1) Motivating(7)
Route ID Task				
Mean	4.9	3.6	3.6	4.3
Median	5	3	4	4
Table Task				
Mean	4.7	4.9	3.3	4.1
Median	5	5	3	4
Other Work				
Mean	5.8	4.9	1.9	3.9
Median	6	4.5	1	4

Desirability of Modes*

	Least Desirable(1)-Most Desirable(4)			
	FTF	Synch + V	Synch-V	Asynch
Mean	3.8	2.9	2.0	1.3
Median	4	3	2	1

*FTF more desirable than Synch + V (Sign Test, $p = .022$)
Synch + V more desirable than Synch-V (Sign Test, $p = .004$)
Synch-V more desirable than Asynch (Sign Test, $p = .022$)

Experimental Modes

Face-to-Face (FTF). The face-to-face mode was the most desirable for the participants. The shared workspace allowed immediate access to the other participant and immediate feedback for all actions or utterances. Non-verbal cues and feedback were observed during the task. While proposing trial routes for consideration, each participant appeared willing to risk the disapproval or censure of his partner. The tendency in this mode was to propose something immediately and then rely on the partner to provide feedback on the appropriateness of the solution proposed. Although the first proposal may have little worth, it did serve as a starting point, and was modified to provide an acceptable solution. This mode did have the most instances of uninhibited language. Such language normally reflected frustration, sarcasm, or at times real disgust with the partner. Previous literature describing the use of uninhibited language indicated that the separated, computer-mediated modes would yield a higher incidence of this type of language. (See discussion following on uninhibited language.) A high volume of task oriented [TO] language was demonstrated in this mode. This is due to the greater amount of communication between the participants, redundant statements, and the necessity to discuss in great detail the proposed route, as the proposed route often was rather vague and not well thought out. The solutions achieved and the time required were essentially the same as with the synchronous mode with voice added. It was observed that other work was only done while one participant was entering the solution into the computer. No other work was accomplished while the task was being solved.

Synchronous with Voice (SYNCH + V). This mode was hypothesized to be most similar to FTF and was rated by the participants as the next most desirable mode. Immediate voice feedback was available and visual cues were available during the marking of the shared computer map. It was observed that the participants were not as willing to risk the censure or disapproval of their partner in this mode. The first route proposed by a participant was deliberated more than those first proposed in FTF. The proposed route that was recommended by one participant to the other was normally well thought out and precisely described. The responses to the proposed route were focused on attempting to understand exactly what was proposed, and then providing modifications to the proposed route so that the requirements were met. The visual cues consisted of pointing to items and annotating on the shared map display. Some instances of uninhibited language [U] were still demonstrated, once again expressing the frustration of one of the participants. Other work was accomplished during task accomplishment for this mode. The participants were comfortable turning away from the shared screen to do other work, while their partner was marking something or transitioning from program to program. They relied on their partner to speak to them if they were needed or something required their attention.

Synchronous without Voice (SYNCH-V). This mode was rated as a less desirable mode than either FTF or SYNCH + V. The post-experiment questionnaire indicated that the lack of a voice channel was the primary reason for this rating. The participants proposed deliberated routes and responded to their partner with alternative solutions, rather than just stating that a proposal was acceptable or not acceptable. However confusion [C] was demonstrated in this mode as the participants seemed to have some difficulty in understanding the intent or meaning of their partner, especially since responses and feedback were at times delayed. Feedback, although only delayed by reading, typing and comprehension time, was certainly not immediate. The difficulty experienced, from a communication standpoint, occurred while the participants were trying to decide on a mutually acceptable route, using typed communications, rather than when they were working on the shared screen. At times, in an apparent attempt to speed communications, some reliance on abbreviations [A] was observed; this at times appeared to contribute to misunderstandings of intent. While working on the shared screen, visual cues and feedback allowed for adequate information exchange and provided a sense of confidence in accomplishing the task. The route scores achieved for this mode, compared to FTF, were not as good. It was observed that there was a reluctance on the part of the participants to pursue alternative, possibly better solutions, once an acceptable solution had been determined. This may have been due to the time constraint imposed. The participants were reluctant to turn away from the computer screen and accomplish other work. This resulted in a slower Other Work rate. If they turned away from the screen, there was a risk that they would not immediately see a message from their partner. While the participants were using the shared pointing device and a shared text entry capability, it was observed, that at times, they had difficulty in determining who was controlling the device and who would take the lead in marking on the shared map display and shared message window.

Asynchronous (ASYNCH). Rated as the most difficult of the modes, ASYNCH took longer, required more computer manipulations to transition between programs, involved delayed communications and provided for no immediate or real time feedback. The participants provided trial route proposals only after insuring that their proposal was totally acceptable from their own standpoint. Instances of uninhibited language [U] criticizing a proposal or a participant were very infrequent. However, all participants reported experiencing frustration and confusion. Communication was limited, as shown by the relatively small number of total words [TOTW] used, but focused to the task. Most communications dealt with task oriented [TO] information. It was apparent that the lack of real time communications allowed the participants to lose track of the status of the task. At times, some participants appeared totally oblivious to what their partner was doing. Although seeming to be willing to correct mistakes, they were not willing to take the initiative to use the extra communication time required to pursue alternative solutions; however the route scores, compared to FTF, were not statistically different. More time was available for other work during this mode than for any other.

Task Activity Variables

Graphic Displays. While using shared displays in the two synchronous modes, the participants became quite adept at communicating without speaking or providing text messages. They were able to use the shared pointer to point to areas of interest; and by using the keyboard alpha-numerics were able to annotate proposed routes, bridges and obstacles, and indicate approval or disapproval. It appears that a more sophisticated and complete graphical language may be able to replace voice and text communications completely, without adversely affecting the task accomplishment.

Text Based Communication Tasks. Use of typed communications, for the Route Selection Task, appeared to inhibit the sharing of ideas, and the proposal of alternative courses of action. A free flowing discussion was rarely observed. Rather, a solution was proposed, modified by the other participant, and approved by the team. The typed message-based system allowed successful task accomplishment, but did not enhance or improve the exchange of information or ideas.

Media Variables

Memory available in Computer-Mediated Communication. The computer allows for storage of data and can remember the actions that have previously been accomplished. It was necessary, at times, for the participant to review the previous message or proposed route. This was especially true in the ASYNCH mode when responses and data sharing were delayed. However, the task did not make heavy use of historical, stored information so this strength of ASYNCH was not tested and factored into the overall comparison of modes.

Asynchronous versus Synchronous Communication. It would have been reasonable to hypothesize that the ASYNCH mode would permit a more deliberate exchange of information, and thereby possibly allow a better solution to the problem. Any benefit occurring from increased deliberation in exchanging information was outweighed by the perceived disadvantage by the participants of longer communication times.

Communication Efficiency. Graphical communication was efficient, easily understood, task oriented, and in the synchronous mode, provided immediate feedback. Textual communication was normally succinct, at times misunderstood, task oriented, and did not provide for immediate feedback during the ASYNCH mode.

Uninhibited Language. Although it was hypothesized that the voiceless modes of communication would result in a greater use of uninhibited language between participants (Weisband, et al., 1988), in fact the opposite occurred during this experiment. The instances of uninhibited language decreased across modes (FTF, SYNCH+V, SYNCH-V, and ASYNCH). It appears that proximity of participants and time available were the important factors, rather than voiceless versus voice communications.

Group Effects

Leadership. Although no leader was designated for the task, a leader usually surfaced. This leader emerged very early in the training trials, usually in an attempt to compensate for obvious confusion or lack of confidence on the part of the other participant. Although possibly not a leader in terms of decision making, he was the leader in the process of accomplishing the task. When a leader emerged, he normally proposed the first trial route, directed task activities if they were bogged down, was usually deferred to if alternative proposals were equal, and provided task and process information if the partner was confused. Dyads that demonstrated high competence and confidence levels during the training sessions did not develop a specific leader.

Consensus Development. FTF allowed many alternatives to be discussed and also permitted distracting non-task discussions. The separated modes allowed consensus to be achieved commensurate with the rapidity of communication, but fewer alternatives were proposed. Less communication occurred, especially in the voiceless conditions, however, most discussions were centered on task accomplishment.

The following table summarizes the data, results and observations of each of the modes of communication.

Table 9

Communication Mode Summary

MODE	FINDINGS and OBSERVATIONS
FTF	- Most desired by participants - Many alternatives discussed - High incidence of uninhibited language - Very little other work accomplished while involved in task activities
SYNCH + V	- Second most desired by participants - Results not significantly different from FTF - More deliberation on first route proposal than in FTF - Provided for immediate feedback and allowed for notification by partner of upcoming event
SYNCH-V	- Alternative solutions proposed rather than outright rejection of partner's proposal - Difficulty in understanding proposals and intent - Tendency to accept a minimally acceptable route - Slowest other work rate
ASYNCH	- Least desired mode - No difference in quality of solution, but took approximately 5 times as long to accomplish as compared to FTF and Synch + V - Initial proposals and alternatives were well deliberated prior to sending to partner

CONCLUSIONS

The differences between face-to-face and synchronous with voice were negligible. At this point there appears that little is lost in terms of performance quality or speed when transitioning from face-to-face to computer-mediated communications with an auxiliary voice channel. There were notable differences from these two modes to synchronous without voice and asynchronous modes. The existence or nonexistence of a voice communication channel appears to be most responsible for performance differences rather than physical separation or computer-mediation. The communication time delay in the asynchronous mode may be an important design consideration for future C2 workstations and problem solving procedures.

Designers of command and control systems should consider computer mediation as a viable alternative to face-to-face and voice only communications. The lethality of the battlefield increases the desirability of dispersion, from a survivability standpoint. The benefits of computer aiding, shared graphics, shared data bases, and two-way graphic communication have the potential of creating an environment that accommodates distribution of function and dispersion of assets.

Asynchronous communications would be the most desirable technological solution because of lower demands on communication systems and synchronization of individual work schedules. However, slow communications and lack of computer time-sharing contributed heavily to the poor performance, based on time, of the asynchronous mode in this study. It is expected that an asynchronous system could support performance as good as other modes if it allows: built in task specific activities, routine "work", message waiting "alerts", access to numerous data bases, and access to several communication nets. This optimized asynchronous mode would make use of multi-tasking capabilities, windowing, faster communication rate, multiple phone lines, automatic queuing of outgoing messages, and possibly a means to allow more timely access of key messages and information. Further research needs to be done to determine if these features in an asynchronous mode support acceptable levels of performance.

More specifically, further investigation of the voiceless condition, should be pursued using a graphics communication language. A graphics language may decrease or possibly eliminate the need for auxiliary voice or text communications. This graphics language should focus on dialogue for all command and staff tasks. The voiceless conditions investigated in this study required the separated team members to type text messages. It is hypothesized that a graphics communication language could eliminate the need for auxiliary voice or text communication. The development of an appropriate graphics language could modify the decrement noted with the voiceless conditions of the current study.

The current study dealt with work shared by a dyad; however, these results do not readily extrapolate to supervised shared work. Computer-mediated communications may have pronounced effects on the ability of a third person to supervise a dyad performing the type of military task investigated in this study. A follow-up experiment is being conducted to look at computer-mediated work of a triad with one team member performing supervisory functions.

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APPENDIX A

TASK DESCRIPTION, INFORMATION, AND INSTRUCTIONS

GENERAL MOVEMENT PLAN TASK DESCRIPTION

This laboratory task addresses some of the sub-tasks of a major staff task. The major staff task, write a movement plan, is a G3 (operations) task that requires coordination among major functional staff groups, and collaboration within each functional staff group. The sub-tasks addressed here require: route selection and computation and creation of movement tables.

The participants are placed in two primary settings, Face-to-Face (FTF), and separated. While performing the task FTF, the participants use paper maps, pencils, calculators, and a computer terminal to record solutions. They perform the task without restriction on their interaction. While separated, three modes are used, synchronous with voice channel, synchronous without voice channel, and asynchronous without voice channel. During the separated phase of the task, participants will use the computer terminals, voice link when available, paper maps, pencils, calculators; and adhere to an interaction protocol.

PARTICIPANTS ARE GIVEN THE FOLLOWING TASKS

Situation - Mission: Move all vehicles of the XYZ unit from point A to point B. Unit must arrive NLT 1900 day 2, and be prepared to immediately assume the mission of division reserve.

General Guidance:

Populated areas will be avoided where possible.

March serials will initially contain no more than 10 vehicles. Each serial will have a minimum of two radio vehicles, and no more than 10 tracked vehicles. A recovery vehicle must be available to every third serial.

While performing the route selection task, you will find that multiple routes will adhere to the above guidance and will also satisfy the more specific guidance contained in the discussion of task one. However, the objective is to select the optimum route within the time available. Each selected route is to be examined based on the factors of length, asset expenditure, and time required to finish the task. The above factors are more closely examined in the discussion of task one.

Task two, computation of march tables and selection of rest, meal and overnight stops, is of course dependent upon the route selected in task one.

Task two may have more than one correct solution answer, based upon the specific guidance contained in the task two discussion.

Regardless of task as many "other work" questions as possible should be completed.

TASK ONE

Task 1. Determine optimum march route based on capacity of roads/bridges and avoidance of man made and natural obstacles.

Players: Staff engineer section. One individual with responsibility for load bearing considerations (roads and bridges), and if necessary upgrade of load bearing capacity; a second individual responsible for obstacle avoidance, and if necessary clearance. (The problem is set up so that the best solution for each of the players will not necessarily be the best solution for the other player. It will be necessary to coordinate and find an alternative solution that meets the needs of both criteria.)

Roads/Bridges: (participant A)

A. Using map, locate start and stop point for total march.
B. Determine maximum vehicle weight to be considered.
C. Using map, determine general route of march.
D. Determine which bridges/roads cannot support heaviest vehicle.
E. Determine optimum route that can support heaviest vehicle.
F. Coordinate route with staff counter-part.
G. If selected route cannot be used by staff counter-part, repeat steps necessary to determine alternate route. If necessary, bridges and roads may be upgraded to the required capacity. Each selected route must be coordinated with staff counter-part until one "best" route is selected.

Obstacles: (participant B)

A. Using map, locate start and stop point for total march.
B. Using map, determine general route of march.
C. Review criteria for obstacle avoidance.
D. Locate on map, using list provided, obstacles that exceed the criteria.
E. Determine optimum route that provides for obstacle avoidance.
F. Coordinate route with staff counter-part.
G. If selected route cannot be used by staff counter-part, repeat steps necessary to determine alternate route. If necessary, obstacles may be removed to allow passage. Each selected route must be coordinated with staff counter-part until one "best" route is selected.

Requirement:

1. *USING GUIDANCE PROVIDED ASSESS RELATIVE VALUE OF SELECTED TRIAL ROUTE(S)*
2. *SELECT OPTIMUM ROUTE*
3. *MARK SELECTED ROUTE ON OWN MAP* (computer and paper)
4. *MARK OBSTACLES REMOVED, OBSTACLES DRIVEN THROUGH; MARK BRIDGES CROSSED AND UPGRADED*

Data Requirement:

1. Map with various routes marked with load bearing capacities, man made and natural obstacles.
2. List of vehicles and their associated weights.
3. Description of obstacles and an avoidance value.
4. Listing of availability of alternative bridging and obstacle clearance capability. (Removal and upgrading criteria.)

All required data is in your possesion. The data consists of maps, lists and tables. This data is contained in the problem package issued to you.

Specific Guidance:

The shortest route possible will be used.

The task must be accomplished as quickly as possible.

Complete as many "other work" questions as possible.

Populated areas (built up areas) will be avoided where possible. (Traveling through a built up area will add time to the march, and will decrease the relative value of the selected route.)

March column may march through any low value obstacles. (However, marching through a low value obstacle(s) will add time to the march and will decrease the relative value of the selected route.)

One high value and two moderate value obstacles may be removed to allow passage. (The expenditure of resources (men, machines, material and time) to remove these obstacles will decrease the relative value of the route. The relative cost of removing two medium value and one high value obstacle are equal.)

Bridges must accommodate 100% of the weight of the heaviest march vehicles.

One bridge with a capacity of greater than 8 tons and less than 45 tons may be upgraded to 60 tons. One bridge of 45 ton capacity or greater may be upgraded to 60 tons. (The expenditure of resources (men, machines, material and time) to upgrade the bridging will decrease the relative value of the selected route. The relative cost of upgrading a bridge of 8 tons - 44 tons is double the cost of upgrading a bridge of 45 tons or greater.)

A route that is as short as possible, avoids obstacles, takes minimum time to determine, and uses the fewest upgrade and removal assets is optimum. The relative value of the selected route may decrease based upon these factors.

Relative Value:

Task accomplishment within 25 minutes is optimum. An increase in task accomplishment time will decrease the value of the selected route.

Route length of 400 miles or less is optimum. A route length greater than 400 miles decreases the value of the route.

Convoy driving through one or no low value obstacles is optimum. Driving through two or more low value obstacles decreases the value of the route.

Removal of one high value obstacle is equal to the cost of removing two medium value obstacles. Either action will decrease the value of the route.

Upgrade of an 8 ton - 44 ton bridge is twice as costly as upgrading a 45 ton or larger bridge. Either action will decrease the value of the route.

TASK TWO

Task 2. Complete the march tables and mark selected stops on the route. Determine time to start and end march for each day. March times will be based on convoy length and total time for march. Rest stops, meal stops and overnight stopping areas must be selected, and the times for these stops must be factored into the total time for the march.

Players: Staff transportation section. One individual who is responsible for computation of serial start times, serial pass time and serial separation time; also has responsibility for determining initial daily stop time based on night time travel and total daily march time. A second individual is responsible for planning and selecting rest stops, meal stops, and overnight stops. (Coordination will be required to insure that the march guidance is met, and that sufficient time is allocated for rest and meals.)

March Tables: (Participant A)

A. Determine total length of march. (miles)
B. Determine daily length of march.
C. Select daily start and stop time for each serial. (Must adhere to guidance on speed, daylight/nighttime travel.)
D. With staff counter-part, consider and factor in rest stops, meal stops and overnight stops.
E. Modify, as necessary, march tables to reflect counter-parts work.

Programmed Stops: (Participant B)

A. Based on daily length of march, determine number of daily rest stops per serial.
B. Select rest stops and meal stops along route.
C. Coordinate time for rest stops and meal stops with staff counter-part.
D. Determine if overnight stop is required for any march day.
E. If required, select sites and coordinate sites with staff counterpart.
F. Insure all guidance is met and stops are coordinated and incorporated into march tables.

Requirement:

1. *COMPLETE MARCH TABLES*
2. *MARK REST, MEAL AND OVERNIGHT STOPS ON MAP* (paper and computer)

Data Required:

1. Map with selected route marked. (task one)
2. Light data.
3. Make up of march serials.
4. Meals, rest and overnight requirements.
5. Speed of vehicles.
6. Overall march speed and spacing requirements.

All required data is in your possesion. The data consists of maps, lists and tables.

Specific Guidance:

Unit will begin movement at 0700, day 1 and 2.

Unit will not spend more than 12 total hours on the road in one day. (Time to be computed from 0700 until last serial (march element) stops for the day.)

Rest stops of 20 minutes must be planned for every 2 1/2 hours of travel.

Troops will eat hot A ration breakfast, cold C ration lunch, and a hot A ration supper. Troops will be fed at 0600 daily, before start of march.

Although a meal stop may replace a rest stop, a rest stop is not of sufficient length to replace a meal stop. Meal stops will be 30 minutes long. Lead serial will eat lunch and dinner within one hour of 1145 and 1745 respectively.

Average march speed will be 30 miles per hour.

No more than 1 hour per march day will be in darkness, for any serial. Serials will have a thirty minute separation from the tail to the head of the next serial. Each serial will maintain a 100 yard vehicle separation within the serial.

Table A-1

March Serials (Both A and B hold this data)

Serial 1-

Vehicles	Combat Weight	Fuel Capacity	Unrefueled Range
1. 1/4 T/trlr/radio	1/2 T	14 gal gasoline	180 miles
2. 1/4 T/trlr/radio	1/2 T	14 gal gasoline	180 miles
3. 5 T wrkr/radio	8 T	36 gal diesel	400 miles
4. 60 T tank	60 T	175 gal diesel	350 miles
5. 60 T tank	60 T	175 gal diesel	350 miles
6. 60 T tank	60 T	175 gal diesel	350 miles
7. 60 T tank	60 T	175 gal diesel	350 miles
8. 60 T tank	60 T	175 gal diesel	350 miles
9. 60 T tank	60 T	175 gal diesel	350 miles
10.32 T fuel trk *	40 T	36 gal diesel	400 miles

* carries 1500 gal diesel, 600 gal gasoline.

Serial 2-

Vehicles	Combat Weight	Fuel Capacity	Unrefueled Range
1. 1-1/2 T/trlr/radio	4 T	24 gal gasoline	250 miles
2. 1-1/2 T/trlr/radio	4 T	24 gal gasoline	250 miles
3. 1-1/2 T/trlr/radio	4 T	24 gal gasoline	250 miles
4. 26 T IFV	26 T	160 gal diesel	320 miles
5. 26 T IFV	26 T	160 gal diesel	320 miles
6. 26 T IFV	26 T	160 gal diesel	320 miles
7. 26 T IFV	26 T	160 gal diesel	320 miles
8. 60 T tank	60 T	175 gal diesel	350 miles
9. 60 T tank	60 T	175 gal diesel	350 miles
10. 2-1/2 T/trlr	6 T	38 gal diesel	350 miles

Serial 3-

Vehicles	Combat Weight	Fuel Capacity	Unrefueled Range
1. 1/4 T/trlr/radio	1/2 T	14 gal gasoline	180 miles
2. 1/4 T/trlr/radio	1/2 T	14 gal gasoline	180 miles
3. 26 T IFV	26 T	160 gal diesel	320 miles
4. 26 T IFV	26 T	160 gal diesel	320 miles
5. 26 T IFV	26 T	160 gal diesel	320 miles
6. 26 T IFV	26 T	160 gal diesel	320 miles
7. 26 T IFV	26 T	160 gal diesel	320 miles
8. 22 T fuel trk *	24 T	30 gal diesel	310 miles

* carries 1000 gal diesel, 400 gal gasoline.

Table A-1 - (Continued)

Serial 4-

Vehicles	Combat Weight	Fuel Capacity	Unrefueled Range
1. 1/4 T/trlr/radio	1/2 T	14 gal gasoline	180 miles
2. 60 T tank	60 T	175 gal diesel	350 miles
3. 60 T tank	60 T	175 gal diesel	350 miles
4. 60 T tank	60 T	175 gal diesel	350 miles
5. 60 T tank	60 T	175 gal diesel	350 miles
6. 26 T IFV	26 T	160 gal diesel	320 miles
7. 26 T IFV	26 T	160 gal diesel	320 miles
8. 26 T IFV	26 T	160 gal diesel	320 miles
9. 5 T wkr/radio	8 T	36 gal diesel	400 miles
10.32 T fuel trk *	40 T	36 gal diesel	400 miles

* carries 1500 gal diesel, 600 gal gasoline.

Serial 5-

Vehicles	Combat Weight	Fuel Capacity	Unrefueled Range
1. 1/4 T/trlr/radio	1/2 T	14 gal gasoline	180 miles
2. 5 T wkr/radio	8 T	36 gal diesel	400 miles
3. 5 T wkr/radio	8 T	36 gal diesel	400 miles
4. 60 T tank	60 T	175 gal diesel	350 miles
5. 22 T APC	22 T	140 gal diesel	280 miles
6. 22 T APC	22 T	140 gal diesel	280 miles
7. 22 T APC	22 T	140 gal diesel	280 miles
8. 26 T IFV	26 T	160 gal diesel	320 miles
9. 26 T IFV	26 T	160 gal diesel	320 miles

Table A-2

Obstacles (Only B holds this data)

Designator	Description	Value
A ----	road block covered by fire----------	high
B ----	road block not covered by fire------	moderate
C ----	anti-personnel mines----------------	moderate
D ----	road cratered-----------------------	high
E ----	anti-vehicle mines------------------	high
F ----	road block covered by fire----------	high
G ----	road block covered by fire----------	high
H ----	hairpin turn------------------------	moderate
I ----	hairpin turn/anti-personnel mines---	high
J ----	traffic tie up point----------------	0600-0800 high 0800-1600 low 1600-1900 mod
K ----	rail road crossing/siding-----------	moderate
L ----	built up area-----------------------	low
M ----	built up area-----------------------	low
N ----	built up area-----------------------	low
P ----	built up area-----------------------	moderate
O ----	built up area-----------------------	high

* Obstacles marked on map provided.

** Staff participant may remove one high value obstacle and two moderate value obstacles.

Table A-3

Bridge/Road Capacity (Only A holds this data)

Designator	Load Bearing Capacity (T)
AA	12
BB	62
CC	40
DD	66
EE	80
FF	8
GG	8
HH	60
II	80
JJ	6
KK	24
LL	24
MM	24
NN	50
PP	25
QQ	60
RR	60
SS	60
TT	45
UU	8

* Bridge locations marked on map provided.

** Staff participant has the capability to upgrade two bridges; one of a capacity of 8T-44T, and one of 45T or greater.

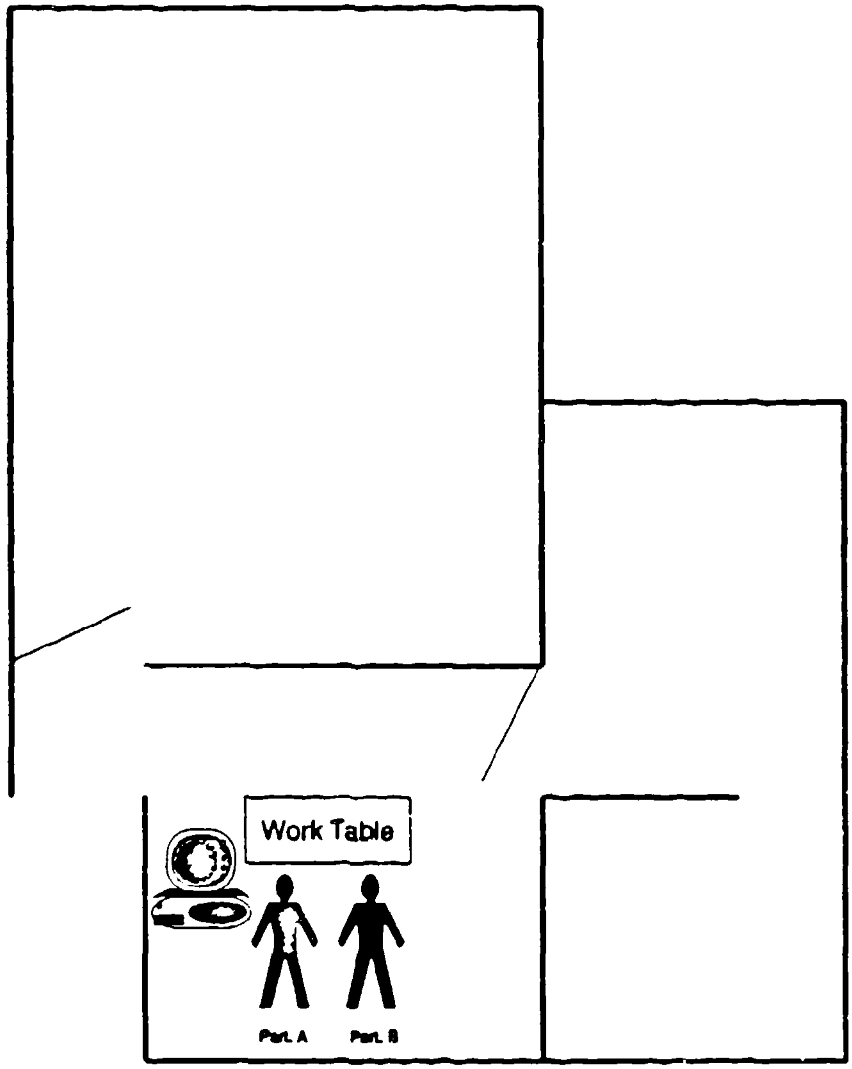
Table A-4

Light Data (Only A holds this data)

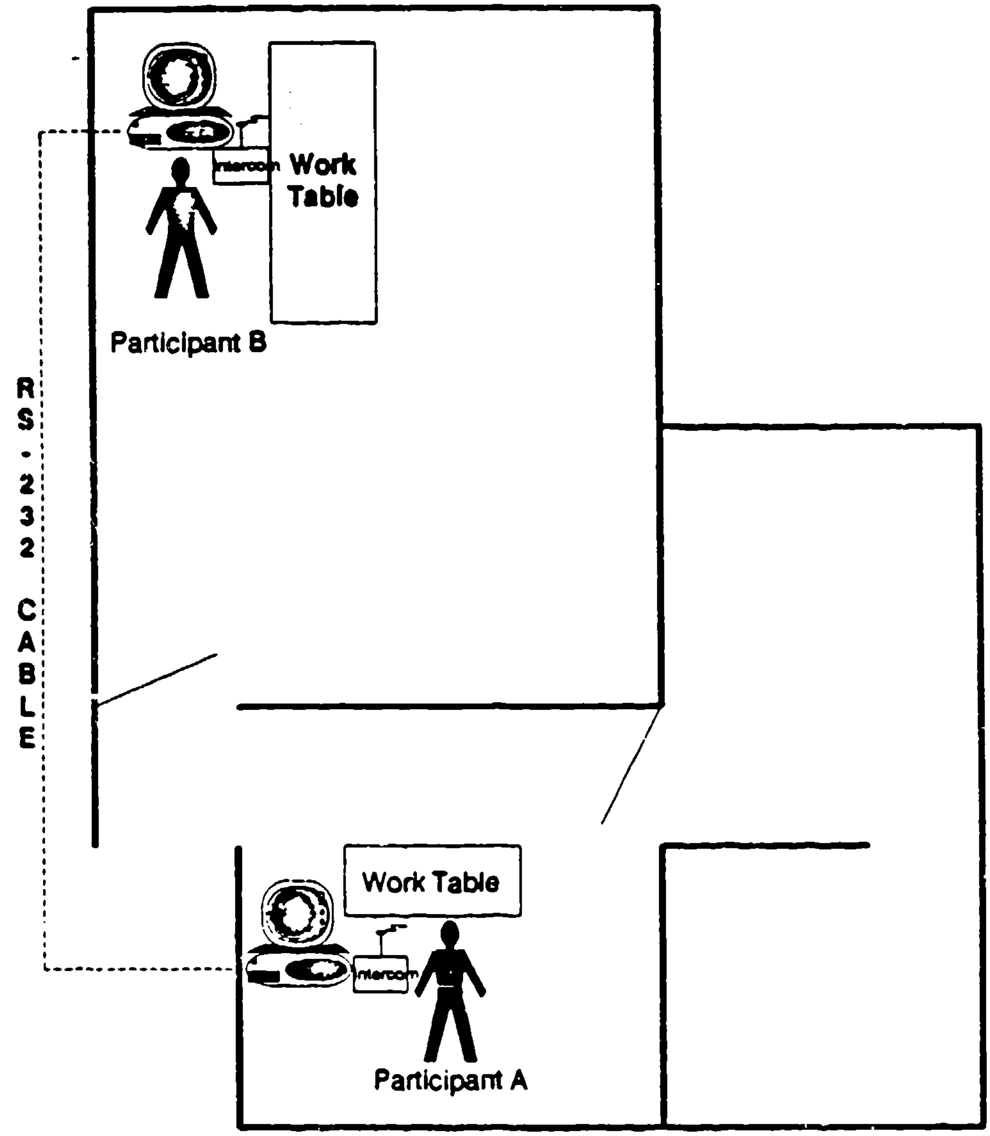
Day	Sunrise	Sunset
1	0636	1713
2	0639	1710
3	0642	1707
4	0645	1704
5	0648	1701

APPENDIX B

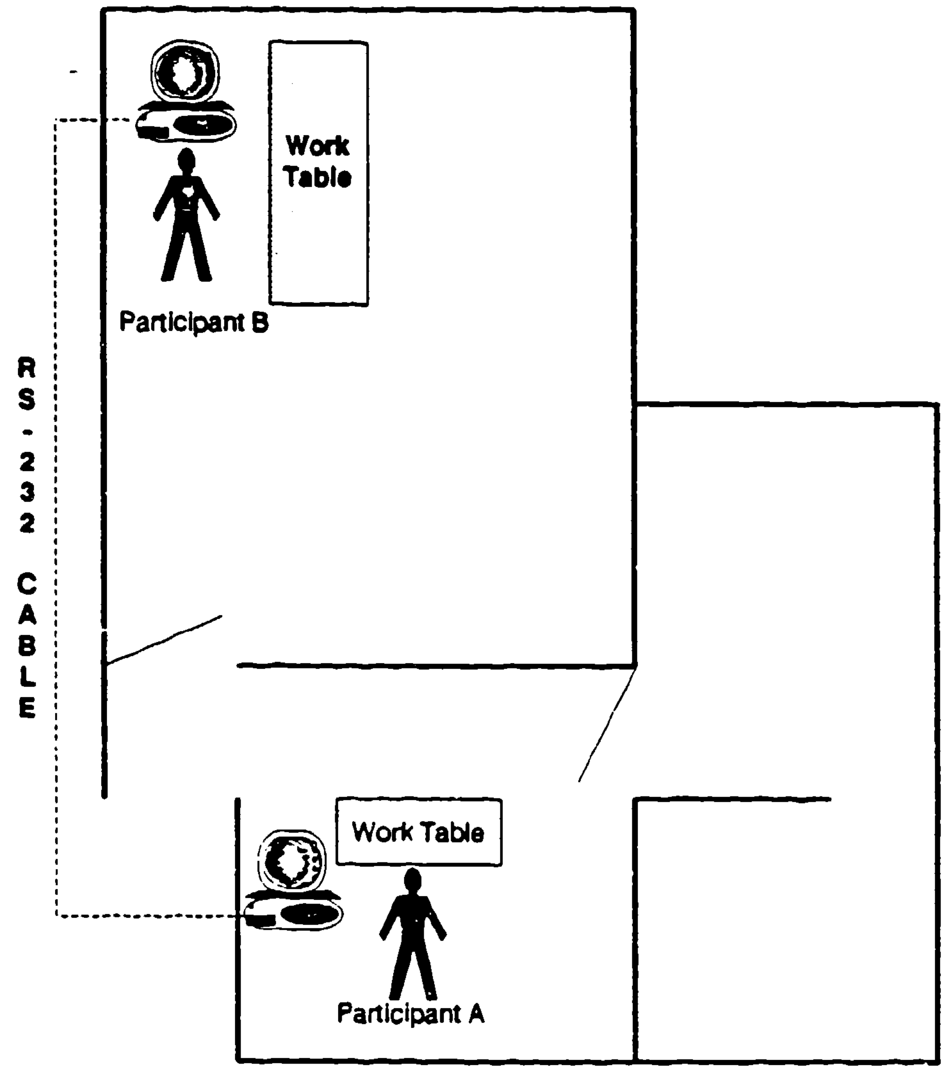
LABORATORY LAYOUT AND DESCRIPTION OF HARDWARE AND SOFTWARE



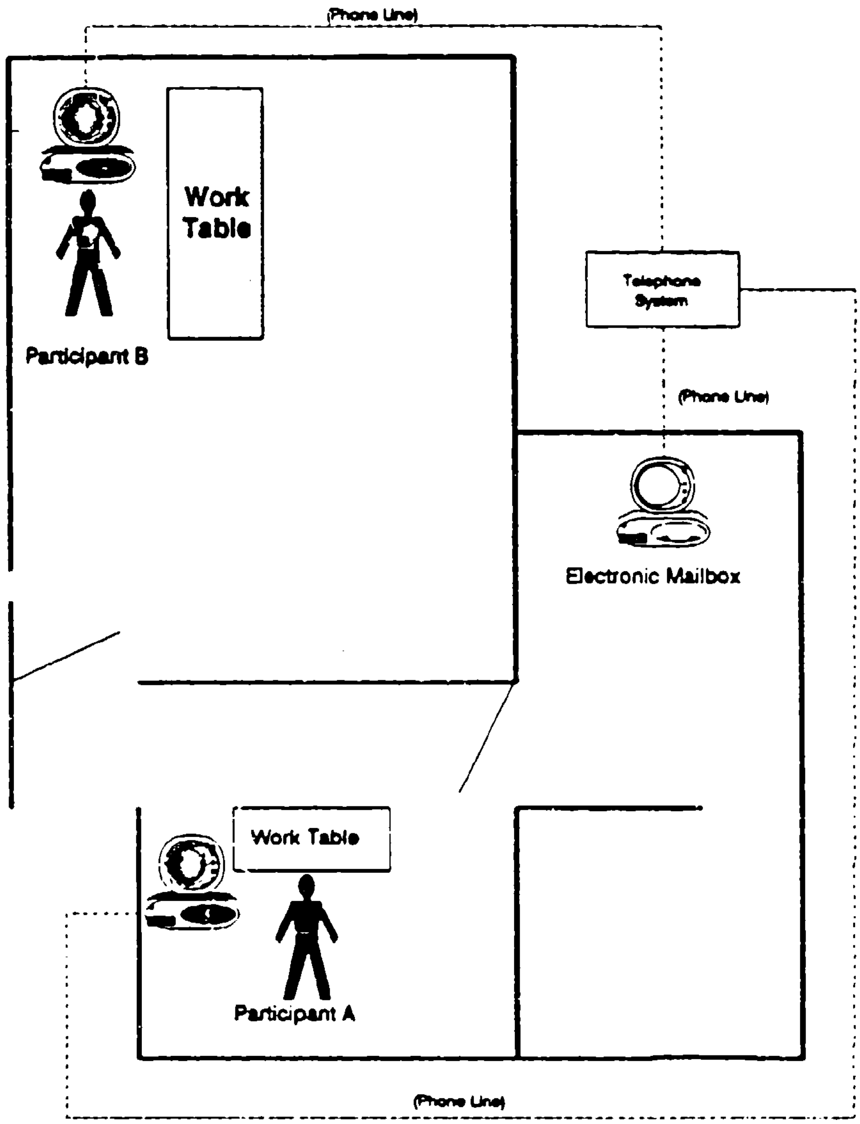
LABORATORY LAYOUT FOR FACE-TO-FACE-DYAD



LABORATORY LAYOUT FOR SYNCHRONOUS WITH VOICE-DYAD



LABORATORY LAYOUT FOR SYNCHRONOUS WITHOUT VOICE-DYAD



LABORATORY LAYOUT FOR ASYNCHRONOUS MODE-DYAD

HARDWARE AND SOFTWARE* USED FOR THE EXPERIMENTAL LABORATORY

The lab as presently configured, consists of four IBM and Compaq personal computers running off the shelf and locally developed software to provide capabilities in communications, graphics presentations, textual exchange of information and the necessary cueing and event highlighting. The focus of the current lab allows experimental subjects to accomplish a military staff task that requires coordination and collaboration from separated (distributed) locations.

The application software presently being used consists of:

(1) Insynch Ver 2.0
(2) Sidekick Ver 2.0.
(3) Superkey Ver 1.16A.
(4) Cross Talk XVI.
(5) PC-DOS 3.2

Software de[illegible]ped by the experimenter provides for:

(1) Data c[illegible], data entry, and creation of time logs.
(2) Confi[illegible]on files.
(3) Setup batch files.
(4) 9 task specific map sets (originally created using PC Paint, presently loaded with INSYNCH software).

The hardware configuration presently being used consists of:

(1) Three IBM PC II with:
   (a) 640 Kb.
   (b) CGA graphic display.
   (c) 360Kb floppy drive. (1 machine has two drives.)
   (d) 20 Mb hard drive.
   (e) 2 serial ports.
   (f) 1 parallel port.
   (g) Epson graphics printer.
   (h) Hayes 1200 external modem.
   (i) Microsoft Mouse.
   (j) Two position data selector. (Modem or Insynch Cable)
   (k) 3 foot male to male RS-232 cable.
   (l) 3 foot male to female RS-232 cable.
   (m) Crossed male to male RS-232 cables for Insynch.

(2) One Compaq portable PC with:
   (a) 256Kb.
   (b) 2 360Kb floppy drives.
   (c) Internal 1200 baud modem.

*Use of this hardware and software does not constitute an endorsement by the U.S. Army.

APPENDIX C

BRIEF GUIDE TO IN-SYNCH SOFTWARE*

In-synch is a memory-resident program that connects two IBM PCs or IBM compatibles together, similar to most communication software. The difference is that In-synch also ties the keyboards together so that a key struck on one machine will cause an identical response on the other terminal. The machines respond as one, though working separately. In-synch requires a machine with at least 384k and each machine in a conference set up must have a different copy (different serial number) of In-synch.

A brief description of In-synch features follows:

STARTING IN-SYNCH

In-synch is loaded into memory at all times and is activated by pressing the shift-ctrl keys simultaneously.

ENDING IN-SYNCH

The In-synch menus include an option for end conference. This will hang up the phone. The system will then return to the In-synch Master Menu (or return to the last DOS operation if running an applications program within In-synch).

HELP

Help will bring up a new screen that has a short description of all the options on the menu presently being displayed. To activate Help press F1.

DIRECT - INDIRECT CALLS

Direct calling--In-synch will dial the phone, make a connect, and pass ID information. Indirect calling--In-synch will only convert an existing voice line to data and pass ID information.

CONVERSION FROM VOICE - DATA OR DATA-VOICE COMMUNICATIONS

This feature allows converting data link to voice so that users can talk over phone line. F2 function key will start the procedure and the system will prompt for all steps. When ready to continue conferencing, any key strike will return phone line to a data line.

*Use of this software does not constitute an endorsement by the U.S. Army.

LOCAL/IN-SYNCH

Allows stopping in-synch of the keyboards temporarily, so that one or both users can work independently. To toggle between Local and In-synch modes press F3.

APPLICATIONS PROGRAM OPTION

This option will return operator(s) to the last DOS operation. User will still be in In-synch's last mode. When entering Local mode, the other user will still be in In-synch. F3 will toggle users from In-synch to Local. This will allow users to reach compatible positions. F3 again will return users to In-synch.

MESSAGE WINDOW

The message window allows users to communicate by typing without affecting the application software. To activate the message window either user can press F4. To return from the message window feature, either user can press Esc.

MINUTES

Minutes are an electronic time-line of In-synch events. Minutes stores start - end of conference, and notes made through the option add notes in the minutes menu. Minutes save the date of the conference and the time of each occurrence. Minutes are stored automatically and at the end of the conference each user will be given the option of saving them to a file.

SNAP SHOTS

When running a program the other user doesn't have, the In-synch snapshot feature enables capturing any text or graphic screen, and sending it to the other user.

TRANSFER DATA

The Transfer Data menu will appear when In-synch first makes connection and synchronizes. This feature anticipates that software may be transferred between systems as needed for conferences. All software to be run at both PCs must reside on both PCs.

APPENDIX D

OVERALL ANALYSIS FOR REPEATED MEASURES OF TASK VARIABLES

Mean scores and standard deviations by communication mode and trial for each dependent variable

	Mode			
	FTF	Synch+V	Synch-V	Asynch
Route ID Time				
MEAN trial 1	1113.625	1116.375	2412.625	6166.125
STANDARD DEV	202.540	306.981	865.582	1471.684
MEAN trial 2	1005.125	1073.500	2380.625	4469.250
STANDARD DEV	395.134	323.474	988.534	1434.739
Table Time				
MEAN trial 1	1749.750	1872.250	3145.250	5025.250
STANDARD DEV	490.588	307.356	1083.080	2058.117
MEAN trial 2	1721.125	1735.000	2420.000	4290.125
STANDARD DEV	496.321	384.539	1133.164	1871.555
Route Agreement Time				
MEAN trial 1	637.875	549.375	1424.625	3635.500
STANDARD DEV	123.050	211.288	588.574	1058.319
MEAN trial 2	501.875	573.875	1224.000	2427.125
STANDARD DEV	157.640	255.962	478.477	697.134
Route Score				
MEAN trial 1	-3.500	-2.500	-4.000	-3.625
STANDARD DEV	0.926	2.000	2.673	1.996
MEAN trial 2	-1.625	-3.625	-5.125	-3.500
STANDARD DEV	0.916	2.504	1.727	2.000
Other Work				
MEAN trial 1	22.750	66.750	54.500	62.000
STANDARD DEV	15.332	37.943	37.675	27.939
MEAN trial 2	66.750	62.750	35.125	89.125
STANDARD DEV	43.279	35.298	22.787	34.779

Overall analysis of task variables. It is a 2 (Trial) X 4 (Communication Mode) completely within subjects design.

Route ID Time

SOURCE	SS	DF	MS	F	P
Trials	3535340.063	1	3535340.063	10.601	0.014
ERROR	2334391.938	7	333484.563		
Comm. Mode	.191925E+09	3	.639751E+08	54.280	0.000
ERROR	.247510E+08	21	1178616.902		
Wilks' lambda = 0.035		3,5		46.477	0.000
Trial X Mode	8040737.063	3	2680245.688	5.431	0.006
ERROR	.103641E+08	21	493528.092		
Wilks' lambda = 0.488		3,5		1.748	0.273

Appendix D - (continued)

Table Time

SOURCE	SS	DF	MS	F	P
Trials	2644689.063	1	2644689.063	4.918	0.062
ERROR	3764420.688	7	537774.384		
Comm. Mode	.890431E+08	3	.296810E+08	13.817	0.000
ERROR	.451103E+08	21	2148110.295		
Wilks' lambda = 0.073		3,5		21.314	0.003
Trial X Mode	1699524.063	3	566508.021	1.034	0.398
ERROR	.115019E+08	21	547708.676		
Wilks' lambda = 0.614		3,5		1.047	0.448

Route Agreement Time

SOURCE	SS	DF	MS	F	P
Trials	2311920.250	1	2311920.250	5.893	0.046
ERROR	2746252.000	7	392321.714		
Comm. Mode	.648913E+08	3	.216304E+08	76.173	0.000
ERROR	5963271.188	21	283965.295		
Wilks' lambda = 0.044		3,5		36.261	0.001
Trial X Mode	3766146.875	3	1255382.292	5.060	0.009
ERROR	5210230.875	21	248106.232		
Wilks' lambda = 0.188		3,5		7.209	0.029

Route Score

SOURCE	SS	DF	MS	F	P
Trials	0.062	1	0.062	0.010	0.925
ERROR	45.938	7	6.563		
Comm. Mode	35.000	3	11.667	2.722	0.070
ERROR	90.000	21	4.286		
Wilks' lambda = 0.299				3.904	0.088
Trial X Mode	24.188	3	8.063	2.879	0.060
ERROR	58.813	21	2.801		
Wilks' lambda = 0.498		3,5		1.683	0.285

Appendix D - (continued)

Other Work

SOURCE	SS	DF	MS	F	P
Trials	74.391	1	74.391	0.292	0.606
ERROR	1782.234	7	254.605		
Comm. Mode	7867.922	3	2622.641	2.614	0.078
ERROR	21068.453	21	1003.260		
Wilks' lambda = 0.242		3,5		5.234	0.053
HYPOTHESIS	4529.297	3	1509.766	2.928	0.057
ERROR	10827.578	21	515.599		
Wilks' lambda = 0.436		3,5		2.154	0.212

APPENDIX E

BOX PLOTS OF TASK VARIABLES

Plots are by mode within each task variable. The plot scale is consistent within each task variable.

```
---------------------------------------------------------------------------
BOX PLOT OF VARIABLE:  Route ID Time, N = 64
           GROUPED BY VARIABLE:     MODE
---------------------------------------------------------------------------
      599.00                                                  7562.00
   MINIMUM                                                  MAXIMUM

      --+--
      +(+ )-----                                                  FTF
      --+--

       -+--
      -(+ )-----                                                  SYNCH+V
       -+--

              ----+-------
        ------(   +    ) +-----------                             SYNCH-V
              ----+-------

                                --------------+-------------
                       ---------+   (         +          ) +----- ASYNCH
                                --------------+-------------
```

```
---------------------------------------------------------------------------
BOX PLOT OF VARIABLE:  Table Time, N = 64
           GROUPED BY VARIABLE:     MODE
---------------------------------------------------------------------------
      915.00                                                  9294.00
   MINIMUM                                                  MAXIMUM

       ----+---
      -+ ( +  )-                                                  FTF
       ----+---

        ---+-
       -+ (++)---                                                 SYNCH+V
        ---+-

            -----+---------
      ------(    +     )  +------                                 SYNCH-V
            -----+---------

                    ------+------------
                 ---(+     +      )    +-------------------------- ASYNCH
                    ------+------------
```

Appendix E - (Continued)

```
---------------------------------------------------------------------------
BOX PLOT OF VARIABLE:  Route Agreement Time, N = 64
           GROUPED BY VARIABLE:     MODE
---------------------------------------------------------------------------
      232.00                                                     5078.00
   MINIMUM                                                     MAXIMUM

       --+-
      -( +)--                                                     FTF
       --+-

       -+--
      -(+)+---                                                    SYNCH+V
       -+--

             ----+-----
         ----(   +   )+-----------                                SYNCH-V
             ----+-----

                            ---------+----------
                        ----+(       +       ) +----------------- ASYNCH
                            ---------+----------
===========================================================================
---------------------------------------------------------------------------
BOX PLOT OF VARIABLE:  Route Score, N = 64
           GROUPED BY VARIABLE:     MODE
---------------------------------------------------------------------------
       -8.00                                                        0.00
   MINIMUM                                                     MAXIMUM

                                      --------+---
                           -----------+  (    +  +)-------------- FTF
                                      --------+---

                               -----------+----------
      -------------------------+ (        +        ) +----------- SYNCH+V
                               -----------+----------

                   ----+-------------------
      --------(----+   +        )         +---------------------- SYNCH-V
                   ----+-------------------

                               -----------+--------
            -------------------+   (      +      )--------------- ASYNCH
                               -----------+--------
===========================================================================
```

Appendix E - (Continued)

```
---------------------------------------------------------------------------
BOX PLOT OF VARIABLE:  Other Work, N = 64
           GROUPED BY VARIABLE:    MODE
---------------------------------------------------------------------------
        9.00                                                      147.00
   MINIMUM                                                     MAXIMUM

           -------------+------------------------
       --(-+            +             )         +------------------ FTF
           -------------+------------------------

                ------------+---------------
       ---------+(          +         )     +----------            SYNCH+V
                ------------+---------------

        --+-----
      -(+ +  ) +----------     *                                   SYNCH-V
        --+-----

                       -------+--------------
         -------------(+      +       )     +------------------    ASYNCH
                       -------+--------------
___________________________________________________________________________
Legend:        * = Outlying value

               +
               + = Median value
               +

              () = 95% confidence interval

          ------
          +    + = Semi-interquartile range (Box)
          ------

             --- = Value within and closest to 1.5 times the
                   semi-interquartile range (Whisker)
```

APPENDIX F

COMMUNICATION MODE ANALYSIS OF TASK VARIABLES

Comparison of Communication modes. The comparison are contrasts between FTF and Synch+V, FTF and Synch-V, and FTF and Asynch.

Route ID Time

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	40470.125	1	40470.125	0.065	0.807
ERROR	4383572.875	7	626224.696		
FTF v Synch-V	.572236E+08	1	.572236E+08	18.144	0.004
ERROR	.220765E+08	7	3153791.714		
FTF v Asynch	.580263E+09	1	.580263E+09	103.418	0.000
ERROR	.392760E+08	7	5610853.982		

Table Time

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	148785.125	1	148785.125	0.198	0.670
ERROR	5255015.875	7	750716.554		
FTF v Synch-V	.350913E+08	1	.350913E+08	10.624	0.014
ERROR	.231206E+08	7	3302941.982		
FTF v Asynch	.273265E+09	1	.273265E+09	26.095	0.001
ERROR	.733024E+08	7	.104718E+08		

Route Agreement Time

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	2178.000	1	2178.000	0.014	0.909
ERROR	1079160.000	7	154165.714		
FTF v Synch-V	.182136E+08	1	.182136E+08	26.199	0.001
ERROR	4866412.875	7	695201.839		
FTF v Asynch	.193878E+09	1	.193878E+09	127.400	0.000
ERROR	.106526E+08	7	1521805.839		

Appendix F - (Continued)

Route Score

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	8.000	1	8.000	1.120	0.325
ERROR	50.000	7	7.143		
FTF v Synch-V	128.000	1	128.000	8.784	0.021
ERROR	102.000	7	14.571		
FTF v Asynch	32.000	1	32.000	3.200	0.117
ERROR	70.000	7	10.000		

Other Work

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	6.125	1	6.125	0.001	0.973
ERROR	33704.875	7	4814.982		
FTF v Synch-V	40044.500	1	40044.500	6.254	0.041
ERROR	44823.500	7	6403.357		
FTF v Asynch	4050.000	1	4050.000	0.862	0.384
ERROR	32882.000	7	4697.429		

APPENDIX G

SOURCE TABLES FOR OVERALL REPEATED MEASURES ANOVA ON DYAD TRANSCRIPT DATA

The repeated measures are trials (1 & 2) and communication modes (FTF, Synch+V, Synch-V, & Asynch). The source tables are in order by dependent variable.

Complete Sentences [COMPLT]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	15221.39	1	15221.39	3.55		0.10
error	30026.48	7	4289.50			
Comm. Mode	342027.80	3	114009.27	10.38		0.00
error	230668.33	21	10984.21			
Trial X Mode	11039.67	3	3679.89	1.14		0.36
error	67803.95	21	3228.76			
Wilks' lambda (mode) = 0.14		DF = 3,5			10.29	0.01
Wilks' lambda (trials X mode) = 0.82		DF = 3,5			0.36	0.79

Declarative Sentences [DECLAR]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	66.42	1	66.42	0.96		0.36
error	485.97	7	69.42			
Comm. Mode	1878.08	3	626.03	4.95		0.01
error	2655.34	21	126.44			
Trial X Mode	238.24	3	79.41	0.64		0.60
error	2588.07	21	123.24			
Wilks' lambda (mode) = 0.30		DF = 3,5			3.91	0.09
Wilks' lambda (trials X mode) = 0.31		DF = 3,5			3.76	0.09

Questions [QUEST]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	19.47	1	19.47	1.01		0.35
error	134.47	7	19.21			
Comm. Mode	2725.60	3	908.53	16.10		0.00
error	1185.23	21	56.44			
Trial X Mode	70.83	3	23.61	1.55		0.23
error	319.40	21	15.21			
Wilks' lambda (mode) = 0.02		DF = 3,5			87.85	0.00
Wilks' lambda (trials X mode) = 0.38		DF = 3,5			2.71	0.16

Appendix G - (Continued)

Exclamatory Sentences [EXCLAM]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	2.98	1	2.98	1.38		0.28
error	15.13	7	2.16			
Comm. Mode	5.68	3	1.89	1.43		0.26
error	27.76	21	1.32			
Trial X Mode	4.58	3	1.53	0.94		0.44
error	34.25	21	1.63			
Wilks' lambda (mode) = 0.61			DF = 3,5		1.08	0.44
Wilks' lambda (trials X mode) = 0.50			DF = 3,5		1.69	0.28

Abbreviations [A]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	1.00	1	1.00	0.17		0.69
error	40.00	7	5.71			
Comm. Mode	618.56	3	206.19	9.07		0.00
error	477.44	21	22.74			
Trial X Mode	131.38	3	43.79	3.92		0.02
error	234.63	21	11.17			
Wilks' lambda (mode) = 0.16			DF = 3,5		8.76	0.02
Wilks' lambda (trials X mode) = 0.32			DF = 3,5		3.57	0.10

Confusion [C]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	26.27	1	26.27	0.95		0.36
error	193.11	7	27.59			
Comm. Mode	1123.17	3	374.39	5.91		0.00
error	1329.95	21	63.33			
Trial X Mode	34.05	3	11.35	0.38		0.77
error	622.08	21	29.62			
Wilks' lambda (mode) = 0.14			DF = 3,5		10.38	0.01
Wilks' lambda (trials X mode) = 0.88			DF = 3,5		0.23	0.87

Appendix G - (Continued)

Grammatical Error [GE]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	0.00	1	0.00	0.00		1.00
error	5.75	7	0.82			
Comm. Mode	0.31	3	0.10	0.11		0.95
error	19.94	21	0.95			
Trial X Mode	2.38	3	0.79	0.48		0.70
error	34.88	21	1.66			
Wilks' lambda (mode) = 0.84		DF = 3,5			0.31	0.82
Wilks' lambda (trials X mode) = 0.87		DF = 3,5			0.25	0.86

General Instruction [GI]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	1164.52	1	1164.52	2.65		0.15
error	3079.36	7	439.91			
Comm. Mode	19988.67	3	6662.89	5.02		0.01
error	27871.95	21	1327.24			
Trial X Mode	1339.67	3	446.56	0.91		0.45
error	10337.95	21	492.28			
Wilks' lambda (mode) = 0.28		DF = 3,5			4.36	0.07
Wilks' lambda (trials X mode) = 0.86		DF = 3,5			0.28	0.84

Processing [P]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	123.77	1	123.77	3.82		0.09
error	226.86	7	32.41			
Comm. Mode	448.67	3	149.56	1.42		0.27
error	2219.20	21	105.68			
Trial X Mode	373.80	3	124.60	3.11		0.05
error	842.08	21	40.10			
Wilks' lambda (mode) = 0.63		DF = 3,5			0.98	0.47
Wilks' lambda (trials X mode) = 0.43		DF = 3,5			2.20	0.21

Appendix G - (Continued)

Polite Language [PO]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	0.00	1	0.00	0.00		1.00
error	4.50	7	0.64			
Comm. Mode	9.50	3	3.17	2.29		0.11
error	29.00	21	1.38			
Trial X Mode	2.25	3	0.75	0.36		0.79
error	44.25	21	2.11			
Wilks' lambda (mode) = 0.57			DF = 3,5		1.24	0.39
Wilks' lambda (trials X mode) = 0.54			DF = 3,5		1.42	0.34

Task Oriented [TO]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	2220.77	1	2220.77	2.47		0.16
error	6283.86	7	897.69			
Comm. Mode	67071.42	3	22357.14	15.93		0.00
error	29476.45	21	1403.64			
Trial X Mode	7172.05	3	2390.68	3.03		0.05
error	16587.83	21	789.90			
Wilks' lambda (mode) = 0.12			DF = 3,5		12.81	0.01
Wilks' lambda (trials X mode) = 0.53			DF = 3,5		1.45	0.33

Task Specific [TS]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	2070.25	1	2070.25	5.08		0.06
error	2855.25	7	407.89			
Comm. Mode	11959.31	3	3986.44	2.36		0.10
error	35506.69	21	1690.79			
Trial X Mode	538.88	3	179.63	0.20		0.90
error	18962.63	21	902.98			
Wilks' lambda (mode) = 0.43			DF = 3,5		2.22	0.20
Wilks' lambda (trials X mode) = 0.92			DF = 3,5		0.15	0.92

Appendix G - (Continued)

Uninhibited Language [U]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	0.77	1	0.77	0.13		0.73
error	40.86	7	5.84			
Comm. Mode	148.30	3	49.43	5.04		0.01
error	206.08	21	9.81			
Trial X Mode	8.30	3	2.77	0.43		0.73
error	134.58	21	6.41			
Wilks' lambda (mode) = 0.41			DF = 3,5		2.39	0.18
Wilks' lambda (trials X mode) = 0.80			DF = 3,5		0.42	0.75

Number of Different Words [DIFFW]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	6045.06	1	6045.06	3.68		0.10
error	11494.94	7	1642.13			
Comm. Mode	135473.38	3	45157.79	7.45		0.00
error	127331.63	21	6063.41			
Trial X Mode	2470.56	3	823.52	0.28		0.84
error	61189.44	21	2913.78			
Wilks' lambda (mode) = 0.20			DF = 3,5		6.64	0.03
Wilks' lambda (trials X mode) = 0.87			DF = 3,5		0.26	0.85

Number of Total Words [TOTW]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	432964.00	1	432964.00	4.41		0.07
error	687893.75	7	98270.54			
Comm. Mode	6079129.31	3	2026376.44	7.57		0.00
error	5624917.44	21	267853.21			
Trial X Mode	230418.13	3	76806.04	0.60		0.62
error	2667903.13	21	127043.01			
Wilks' lambda (mode) = 0.23			DF = 3,5		5.71	0.05
Wilks' lambda (trials X mode) = 0.82			DF = 3,5		0.35	0.79

Appendix G - (Continued)

Mean Length of Message [MLM]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	0.42	1	0.42	0.69		0.43
error	4.30	7	0.61			
Comm. Mode	335.68	3	111.89	41.19		0.00
error	57.05	21	2.72			
Trial X Mode	1.27	3	0.42	0.30		0.82
error	29.50	21	1.40			
Wilks' lambda (mode) = 0.07			DF = 3,5		22.17	0.00
Wilks' lambda (trials X mode) = 0.85			DF = 3,5		0.30	0.83

Number of Words Per Minute [WDS/M]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	376.36	1	376.36	2.67		0.15
error	987.14	7	141.02			
Comm. Mode	3867.31	3	1289.10	6.00		0.00
error	4515.28	21	215.01			
Trial X Mode	222.34	3	74.11	0.70		0.56
error	2227.27	21	106.06			
Wilks' lambda (mode) = 0.28			DF = 3,5		4.29	0.08
Wilks' lambda (trials X mode) = 0.67			DF = 3,5		0.83	0.53

Number of Messages Per Minute [MSG/M]

SOURCE	SS	DF	MS	Univar F	Multivar F	P
Trials	13.15	1	13.15	2.06		0.19
error	44.62	7	6.37			
Comm. Mode	241.85	3	80.62	10.12		0.00
error	167.30	21	7.97			
Trial X Mode	12.38	3	4.13	0.90		0.46
error	95.75	21	4.56			
Wilks' lambda (mode) = 0.15			DF = 3,5		9.16	0.02
Wilks' lambda (trials X mode) = 0.63			DF = 3,5		0.98	0.47

APPENDIX H

COMPARISON OF COMMUNICATION MODES FOR TRANSCRIPT DATA

Complete Sentences [COMPLT]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	240818.00	1	240818.00	2.90	0.13
error	581466.00	7	83066.57		
FTF v Synch-V	839808.00	1	839808.00	10.54	0.01
error	557796.00	7	79685.14		
FTF v Asynch	1127251.13	1	1127251.13	15.41	0.01
error	512035.88	7	73147.98		

Declarative Sentences [DECLAR]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	119.35	1	119.35	1.34	0.29
error	624.92	7	89.27		
FTF v Synch-V	115.52	1	115.52	0.30	0.60
error	2692.34	7	384.62		
FTF v Asynch	5967.78	1	5967.78	12.22	0.01
error	3418.61	7	488.37		

Questions [QUEST]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	499.28	1	499.28	4.19	0.08
error	834.66	7	119.24		
FTF v Synch-V	718.21	1	718.21	1.96	0.20
error	2560.70	7	365.81		
FTF v Asynch	4301.28	1	4301.28	53.44	0.00
error	563.47	7	80.50		

Exclamatory Sentences [EXCLAM]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	0.72	1	0.72	0.69	0.43
error	7.28	7	1.04		
FTF v Synch-V	17.11	1	17.11	2.68	0.15
error	44.68	7	6.38		
FTF v Asynch	10.35	1	10.35	2.10	0.19
error	34.56	7	4.94		

Appendix H - (Continued)

Abbreviations [A]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	50.00	1	50.00	5.65	0.05
error	62.00	7	8.86		
FTF v Synch-V	1225.13	1	1225.13	15.21	0.01
error	563.88	7	80.55		
FTF v Asynch	703.13	1	703.13	4.24	0.08
error	1159.88	7	165.70		

Confusion [C]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	1800.00	1	1800.00	3.02	0.13
error	4174.00	7	596.29		
FTF v Synch-V	2850.13	1	2850.13	7.13	0.03
error	2798.88	7	399.84		
FTF v Asynch	3784.50	1	3784.50	8.56	0.02
error	3095.50	7	442.21		

Feedback [F]

SOURCE	MEAN difference	SD difference	T	DF	P
FTF vs Synch+V	7.25	11.81	1.74	7	.126
FTF vs Synch-V	17.75	20.35	2.47	7	.043
FTF vs Asynch	25.81	17.70	4.12	7	.004

Grammatical Error [GE]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	0.12	1	0.12	0.02	0.90
error	56.88	7	8.13		
FTF v Synch-V	0.13	1	0.13	0.04	0.85
error	22.88	7	3.27		
FTF v Asynch	0.50	1	0.50	0.26	0.63
error	13.50	7	1.93		

Appendix H - (Continued)

General Instructions [GI]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	22898.00	1	22898.00	2.16	0.19
error	74254.00	7	10607.71		
FTF v Synch-V	57970.13	1	57970.13	6.05	0.04
error	67034.88	7	9576.41		
FTF v Asynch	61600.50	1	61600.50	6.47	0.04
error	66599.50	7	9514.21		

Processing [P]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	6.13	1	6.13	0.01	0.91
error	3132.88	7	447.55		
FTF v Synch-V	595.13	1	595.13	1.59	0.25
error	2625.88	7	375.13		
FTF v Asynch	1275.13	1	1275.13	1.82	0.22
error	4913.88	7	701.98		

Polite Lanaguage [PO]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	12.50	1	12.50	2.46	0.16
error	35.50	7	5.07		
FTF v Synch-V	12.50	1	12.50	3.43	0.11
error	25.50	7	3.64		
FTF v Asynch	2.00	1	2.00	1.00	0.35
error	14.00	7	2.00		

Task Oriented [TO]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	65341.13	1	65341.13	5.63	0.05
error	81215.88	7	11602.27		
FTF v Synch-V	180901.13	1	180901.13	20.90	0.00
error	60577.88	7	8653.98		
FTF v Asynch	216153.13	1	216153.13	25.21	0.00
error	60019.88	7	8574.27		

Appendix H - (Continued)

Task Specific [TS]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	14365.13	1	14365.13	1.40	0.27
error	71629.88	7	10232.84		
FTF v Synch-V	42195.13	1	42195.13	8.06	0.03
error	36665.88	7	5237.98		
FTF v Asynch	28084.50	1	28084.50	3.69	0.10
error	53255.50	7	7607.93		

Uninhibited Language [U]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	171.13	1	171.13	6.38	0.04
error	187.88	7	26.84		
FTF v Synch-V	312.50	1	312.50	6.52	0.04
error	335.50	7	47.93		
FTF v Asynch	544.50	1	544.50	7.79	0.03
error	489.50	7	69.93		

Number of Different Words [DIFFW]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	83232.00	1	83232.00	3.01	0.13
error	193370.00	7	27624.29		
FTF v Synch-V	318801.13	1	318801.13	13.91	0.01
error	160413.88	7	22916.27		
FTF v Asynch	448878.13	1	448878.13	14.78	0.01
error	212644.88	7	30377.84		

Number of Total Words [TOTW]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	3547116.13	1	3547116.13	1.78	0.22
error	13970750.88	7	1995821.55		
FTF v Synch-V	15964075.13	1	15964075.13	10.74	0.01
error	10403629.88	7	1486232.84		
FTF v Asynch	18635512.50	1	18635512.50	11.88	0.01
error	10982601.50	7	1568943.07		

Appendix H - (Continued)

Mean Length of Message [MLM]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	35.70	1	35.70	5.20	0.06
error	48.05	7	6.86		
FTF v Synch-V	220.50	1	220.50	17.72	0.00
error	87.10	7	12.44		
FTF v Asynch	1173.70	1	1173.70	87.81	0.00
error	93.57	7	13.37		

Number of Words Per Minute [WDS/M]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	954.85	1	954.85	0.63	0.45
error	10661.14	7	1523.02		
FTF v Synch-V	9460.00	1	9460.00	7.98	0.03
error	8296.41	7	1185.20		
FTF v Asynch	10767.78	1	10767.78	9.89	0.02
error	7620.41	7	1088.63		

Number of Messages Per Minute [MSG/M]

SOURCE	SS	DF	MS	F	P
FTF v Synch+V	184.70	1	184.70	3.12	0.12
error	413.90	7	59.13		
FTF v Synch-V	645.12	1	645.12	12.17	0.01
error	371.20	7	53.03		
FTF v Asynch	763.43	1	763.43	16.28	0.00
error	328.23	7	46.89		